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An Object-Oriented XML Schema for the MIP Joint Command, Control, and Consultation Information Exchange Data Model

Michael Gerz, Francisco Loaiza, Erik Chaum

Semantic interoperability among command and control information systems is critical to information sharing and proper automated processing. To improve multinational combined and joint mission capabilities, the Multilateral Interoperability Programme (MIP) has defined the Joint Command, Control, and Consultation Information Exchange Data Model (JC3IEDM), which is gaining wide acceptance beyond the MIP community.

In this paper, we present a reference XML schema definition (XSD) that has become an integral part of the JC3IEDM 3.0 specification. It provides an object-oriented view on the data model and aims at simplifying and accelerating the adoption of the MIP data model in service-oriented architectures and web application development.

We provide the use cases and design principles that have lead to this XSD. Moreover, we show how this type of XML schema can be obtained in an automated way from any relational schema in third normal form by applying only structural and syntactic transformative rules. The application of the XSD is demonstrated by instance XML documents that describe an operational scenario.

Keywords: XML, XML Schema, XSD, Multilateral Interoperability Programme, MIP, JC3IEDM, STANAG 5525

1. Introduction

Semantic interoperability among command and control information systems (C2IS) is critical to information sharing and effective automated processing. To improve multinational combined and joint mission capabilities, a voluntary multinational community of interest (COI) has developed and worked over many years to address the fundamentally difficult task of building community consensus and semantic standards for command and control information exchange. This work is being done by the *Multilateral Interoperability Programme* (MIP; `http://www.MIP-site.org`) which is currently comprised of 25 nations, the North Atlantic Treaty Organization (NATO), and the US Allied Command Transformation (ACT). The MIP documents its conceptual and semantic consensus in an entity-relationship data model, the most recent of which is the *Joint Command, Control, and Consultation Information Exchange Data Model* (JC3IEDM; see MIP, 2005). The JC3IEDM and its predecessor, the C2IEDM, are gaining wide acceptance beyond the MIP community as a foundational core component for command and control semantic interoperability. The JC3IEDM edition 3.0 was published by the MIP in December 2005. Its adoption

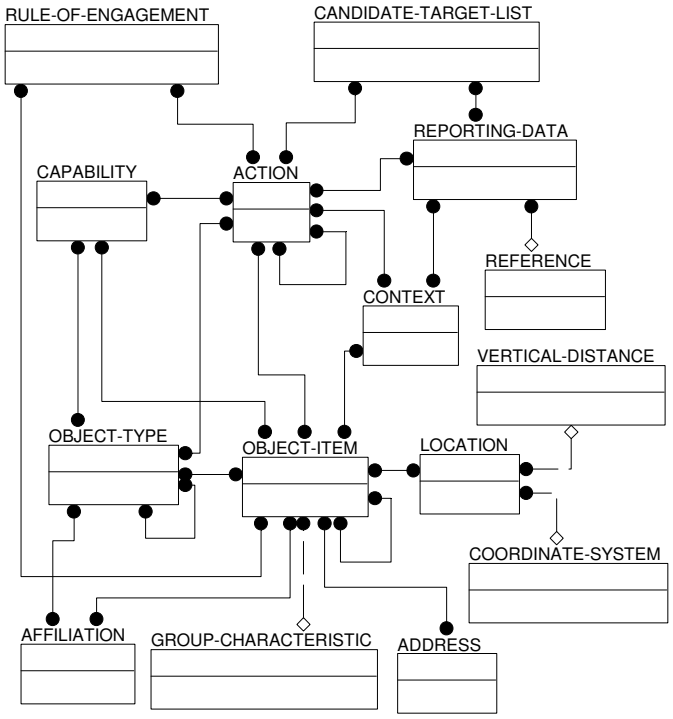


Figure 1: JC3IEDM Independent Entities (IDEF1X Notation)

by NATO, and the ongoing NATO ratification as STANAG 5525, will strongly influence the development of future C2ISs.

The JC3IEDM has a very rich capability to express both operational and tactical context. Much more than a simple tactical picture, the MIP's operational analysis process has defined a set of information exchange requirements that support the commander across a spectrum of types of operations and activities (e.g., planning, coordination, execution, observing, and decision making). Figure 1 shows a high-level independent entity-relationship view of the JC3IEDM. The C2IEDM and JC3IEDM have the essential common characteristic of being generic (i.e., not derived directly from system-specific implementations) and extensible (i.e., suitable as a core to which functional extensions can be added).

This last point is critical because without a shared core set of concepts and semantics each functional community of interest will build unique incompatible representations of the battlespace. This results in higher costs to develop and integrate systems and services and results in limited information exchange and automated processing capabilities due to the limitations of mediation (i.e., mapping or translating). If mediation produces a complete and precisely equivalent representation then the mapping was completely syntactic (i.e., the exact same representation was developed twice – a low probability event). Most often this is not the case and mapping and translation are incomplete, imprecise, contextually loose, and produce an ambiguous result. This limits interoperability, the users' trust and understanding of the information being shared, and in the end operational effectiveness.

Recently, many national and international projects have been initiated to explore the benefits of XML technologies and Web Services in the C2 area. Exposing unique semantics in XML does not address the fundamental limitations of mediation. While XML simplifies the processing of documents by means of a uniform syntax, there is still a need to have a common understanding of the information to be exchanged, i.e., the set, and structure, of the XML elements used for information exchange and their semantics have to be defined.

Information models are essentially specifications of semantics and syntax. Thus, it makes sense to use the JC3IEDM as a multinational, system-independent standard for XML C2 semantics. To avoid diverging and incompatible exchange formats in each individual project, there should be reference XML schema definitions (XSDs) based on the data structures contained in the JC3IEDM. The MIP community has addressed this demand by developing two standardized XML schemas.[1]

The first reference MIP XML schema, namely the *RDBMS XSD*, reflects the relational view of the JC3IEDM. It addresses information exchanges among relational databases whose physical schemas are based on the JC3IEDM specifications. The design of the second reference MIP schema has been motivated by the perceived need to support Web Service (WS) applications within the C2 community. It provides an object-oriented view of the data model and aims at simplifying and accelerating the adoption of the MIP data model in service-oriented architectures and web application development. The object-oriented reference MIP XML schema (WS/OO XSD) does not make any assumptions on the physical storage of operational data and yet allows checking many of the referential integrity constraints of the JC3IEDM during instance XML document validation. These features make the WS/OO XSD very attractive to applications that do not necessarily rely on, or need a JC3IEDM-compliant relational database (e.g., for persistence), or which do but desire to present an object-oriented exchange service.

It should be noted that the design rationale for both XML schemas and their associated technical artifacts are now part of the official JC3IEDM 3.0 specification.

In this paper, we present the object-oriented reference MIP XML schema. In section 2, we provide the use cases and requirements that have lead to the WS/OO XSD. In section 3, we show how this type of XSD can be obtained from any relational schema in third normal form by applying only structural and syntactic transformative rules. The generality of this approach enables the model and XSD to be extended by functional communities. The application of the WS/OO XSD is demonstrated by an operational scenario in which a contingency plan for a composed military obstacle is generated, and updated (section 4 and appendix A). Based on the example, we show that the WS/OO XML schema is not restricted to one particular information exchange mechanism. In section 5, we describe a tool kit that allows, in an automatic way, deriving the XSD and corresponding Java classes. The paper closes with a summary in section 6.

2. XML Use Cases and Schema Requirements

XML is a universal information exchange syntax with wide acceptance in industry. It can be used in various types of applications and use cases. In the context of MIP, six potential use cases were identified:

- Data exchange:
  - Web Services (e.g., exchange of business objects).
  - Exchange with non-MIP databases.
  - MIP XML Exchange Mechanism (exchange among MIP databases via XML).
- Transformation services:

[1] The results presented in this paper have been developed within the XML Working Party of the MIP. Apart from the authors, the members of the XML WP are (in alphabetical order): Fred Burkley (US, Naval Undersea Warfare Center), Gerald Ortner (NHQC3S, NDA), and Cecilia Unell (SE, Combitech AB).

- Supporting tactical communications interfaces, e.g., ADatP-3 or USMTF (effectively almost always lossy).
- Mediation between different versions of the MIP data model.
- Export to various output/presentation formats, e.g., STANAG 5500-conformant messages or HTML.

It is recognized that an optimal schema design can only be achieved in the context of a specific set of detailed requirements. For each use case described above, we can derive different requirements on the XML schema. The requirements are partially contradictory, i.e., no single XML schema fits all purposes equally well. For instance, information exchange between MIP databases and mediation between different data model versions requires an XML schema that facilitates easy integration into MIP-compliant systems and a simple mapping to the JC3IEDM relational database schema. These requirements are met by the MIP RDBMS XSD. For information exchange via web services, the focus shifts to simple integration into object-oriented applications. Here, the strict technical adherence to a relational data model may be considered as a hindrance to efficient data processing. The WS/OO XML schema addresses this requirement.

In the following, we discuss three factors from which we derive requirements on the XML schema design. These factors are (a) the type of sender/receiver of the XML message, (b) the information exchange mechanism, and (c) existing XML standards.

2.1. Requirements Derived from Sender/Receiver

The sender/receiver of an XML message may either be a person, a generic XML viewer (e.g., a web browser), or a C2 information system. In the latter case, we can distinguish between systems that maintain a JC3IEDM-compliant relational database and systems that use a proprietary data model internally and make their data persistent in an arbitrary way, e.g., in an object-oriented data base.

Systems that do not store their data in a MIP-compliant RDBMS can greatly benefit from an XML schema that abstracts from the relational data model. The same holds for systems that use the JC3IEDM data base schema but for which the MIP *Data Exchange Mechanism* (DEM) is replaced or complemented by web services.

To support modern software development, an XML schema with an object-oriented view on the MIP IEDM is highly desirable. Developers will also require that code fragments, which comply with the XML schema (e.g., Java classes), can be generated efficiently.

If there is no back-end RDBMS to enforce the MIP data model semantics (in particular referential integrity), the XML schema should include semantic constraints for domain values, document consistency (no orphan objects), and, ideally, the JC3IEDM business rules. These can be checked during instance XML document validation.

In a mixed MIP/non-MIP environment, syntactic and semantic transformations are inevitable. The combination of XSL-T and an implementation-neutral object-oriented schema provides a technically mature application path for gateways that mediate between the different worlds.

When the sender/receiver is a person, an XML tag naming convention must ensure ease of readability and comprehension. Software developers working with the XML documents and associated code classes will also benefit from such naming conventions.

2.2. Requirements Derived from Information Exchange Mechanism

There are several possible ways in which systems and/or people may exchange information. We distinguish between three different information exchange mechanisms:

- Message-based communication
- Replication-based communication
- Query-based communication

In the first case, instance XML documents describe referentially complete, self-contained messages.[2] For message-based communication, the XSD must ensure referential integrity within a single XML document according to the rules of the data model. Moreover, the XSD for the MIP IEDM must be generic in that it must be possible to tailor it to specific business object XSDs.

In a replication-based scenario, an initial data load is exchanged and then incremental information updates are transmitted (push technology). For instance, only status updates may be sent, once the corresponding unit has been transmitted.

When a receiver queries data from a provider (pull technology), the query results may not necessarily be complete either. For example, a web client requests information on what units are in a given geographic region. In response, the client receives a report that mentions unit *Bravo* is at location *Alpha* as of time *Tango*. The user subsequently wants to know Bravo's current location. Thus, the web client must be able to refer to Bravo by means of a 'key' (e.g., object identifier, URL, or similar) and the web service must be able to provide a position report update on request, which only contains the information that has changed. There may also be cases in which the query result contains references to objects that are not yet known to the web client. This just-in-time, interactive, pull for relevant data is consistent with web services concepts and complementary to the traditional MIP smart push architecture.

The referential integrity and completeness required by the MIP IEDM has implications for the design of XML schemas and associated web services. The latter two use cases require a reference mechanism such that instance documents can refer to external information. However, one need not necessarily retain all of the synthetic keys of the MIP data model for that purpose. The referential integrity constraints in the XSD that hold for message-based communication must be relaxed in replication- and query-based use cases. It is the responsibility of the web service and client – not of the XSD! – to ensure that external references are used appropriately.

2.3. Requirements Derived from XML Standards

In order to facilitate the validation of XML documents, the XML document format must be formalized by means of an XML schema. The schema itself is specified in a schema language. There are many different schema languages available with varying expressiveness and complexity. An overview of existing schema languages is given by van der Vlist (2001). Currently, the most prominent schema language is XML Schema (W3C, 2004a,b,c). It is the one adopted for the MIP WS/OO XML schema.[3] It is standardized by the World Wide Web Consortium (W3C)

[2] This approach has been adopted by the MIP MEM and the ADatP-3 community before. However, the definition of hundreds of message text formats (MTF) resulted in a variety of different representations for basic information like time and date. Self-contained XML messages based on the JC3IEDM resolve the problem as the entities of the MIP IEDM define standard data elements (SDE).

[3] In the following, the term XML Schema is written in small capitals if it refers to the specification language itself. Otherwise, it refers to the concrete WS/OO XML schema.

and supported by virtually all XML tool vendors. The W3C XML Schema is based on an object-oriented model, i.e., it allows defining types and using inheritance.

Fundamental to achieving multinational and joint network-enabled capability (net-centric or network-enabled operations) is a common structure and language for information handling. XML does not support interoperability automatically. Today, there are hundreds of XML vocabularies; a fact which may account in part for the limited improvement in semantic interoperability despite the commonality of syntax. Therefore, while XML provides new tools for improving point-to-point translations, the long-term objective and big win comes through semantic harmonization.

To that effect, *Naming and Design Rules* (*NDR*) are being developed at the international, multinational and national levels. Their intent is to facilitate the discovery and use of common data elements (standardized XML vocabulary), and to provide additional rigor to the XML standards in order to maximize interoperability and enhance supportability. NDRs specify various aspects of an XML schema: naming of XML elements and attributes, schema versioning, schema modularization, definition of namespaces, (restricted) use of XML Schema constructs, etc. NDRs are mainly concerned with the structure and reusability of XML schemas; they do not answer completely what instance XML documents should look like for a particular use case.

In the WS/OO XML schema, the *Guidance for XML Naming and Design within NATO* (*GXND*; currently only in draft) was applied where practical. The GXND is based on two standards: ISO/IEC 11179 (Metadata Registries, MDR; see ISO/IEC, 2005) and ISO 15000-5 (Electronic business eXtensible Markup Language, ebXML; see ISO, 2005).

3. XML Schema Design

Based on the requirements listed in the previous section, we have developed the reference MIP WS/OO XSD. Structures in instance XML documents conforming to the WS/OO XSD closely match the typical OO concepts, e.g., inheritance and navigability. In particular, the representation of relationships and associations via nesting greatly simplifies the adoption of the MIP IEDM in object-oriented applications. To describe (potentially cyclic) graph structures in the tree-like XML notation, a simple mechanism for referencing objects is provided. Instance XML documents exchanged in accordance with the WS/OO XSD do not prescribe any specific storage format, i.e., the WS/OO XML schema abstracts from the underlying persistence mechanism. This matches with the notion of defining an XML *exchange* format. Developers are able to choose any persistence framework, API, or tool, which simplifies integration.

The XML schema is fully automatically derivable from the MIP IDEF1X (see Wikipedia, 2006b) model by applying syntactic transformations only. In that way, the generation is independent from a particular version of the MIP data model. This approach ensures correctness and minimizes XSD production and maintenance cost. If we had relied on the specific semantics of a particular version of the MIP data model to drive the transformations, we would have had to check the mapping rules as the model changed over time. Moreover, transforms must be traceable – the more we transform away from the relational model, the more difficult it becomes to specify and apply the transformation rules and to prove their correctness.

The WS/OO XSD is primarily based on the logical view of the MIP JC3IEDM. The physical view of the data model contains a few additional MIP DEM-specific attributes and is designed for an RDBMS implementation. However, all types of web-services should be supportable by the WS/OO XSD, which is more readily accomplished when basing the specification on the semantics of the logical view of the MIP IEDM.

In this section, the mapping rules are described that are applied to the MIP data model in order to produce the object-oriented XML schema. These rules create a faithful representation of the model. The focus of the following description is on what instance XML documents look like rather than on the technical details of the XML schema definition. The WS/OO XSD comes along with a tool set (see section 5), such that the whole transformation process – starting with the MIP data model in ERwin XML format and ending with the XML schema files – is traceable. The WS/OO XSD and the tool set are available at the MIP web site and considered a normative part of the reference MIP WS/OO XSD specification.

For a complete mapping, transformation rules must be defined for names, domains, entities, attributes, and relationships (including subtyping and associative entities). Moreover, the root element of XML documents must be specified. The mapping rules are described in detail in the following subsections. The MIP XML Working Party worked through a process whereby entity-relationship (ER) modeling constructs were interpreted into UML and then interpreted into an XML design pattern.

3.1. Naming Conventions

To ensure consistency and reproducibility, naming conventions are needed for entities, attributes, and the root element visible in instance XML documents, as well as for simple types, codes, and entity types that only show up in the XML schema definition. Naming of domains, entity types, and attributes in XML is based on the logical view rather than on the physical view of the MIP data model. This enhances readability and comprehension. In accordance with the NATO Naming Guidelines, the UpperCamelCase convention is used for naming XML elements and XML types, whereas the lowerCamelCase convention is used for naming XML attributes.

3.2. Domains

Domains in the ER model are mapped onto XML simple types. The latter are derived from the pre-defined XML Schema types *integer*, *double*, and *string*. Physical restrictions on JC3IEDM domains, i.e., the number of digits for integers, the precision and scale of floating point numbers, and the minimum/maximum length of character strings are reflected in the XSD. Where available, specific range restrictions (e.g., maximum temperature or non-negative quantity) are regarded as well. The upper and lower boundary of numbers is modeled by the XML Schema attributes *minInclusive* and *maxInclusive*. The minimum and maximum length of strings is modeled by means of the attributes *minLength* and *maxLength*.

Codes are represented as strings that are restricted by enumeration. JC3IEDM code values are specified as physical values rather than display values in an instance XML document. This is motivated by efficiency with regard to bandwidth, software development and object persistency. The mapping from the physical values to display values is a matter of national language preference and can be realized easily by means of an XSL-T script. The display values documented by the MIP data model (international English) are included as annotations in the XSD for convenience.

3.3. Entities and Attributes

Entity types in the MIP IEDM are mapped onto complex types in the XML schema definition. In conformance with the NATO XML Naming and Design Rules, attributes in the ER model are specified as XML elements, not XML attributes, exclusively. This simplified approach removes

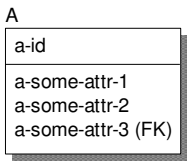
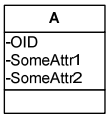
	Design Pattern
IDEF1X	
UML	
XML	<*A*> <OID>...</OID> <SomeAttr1>...</SomeAttr1> <SomeAttr2>...</SomeAttr2> *[relationships]* </*A*> <*A*Ref> <OID>...</OID> *[relationships]* </*A*Ref>

Figure 2: Entities and Attributes

the arbitrary or even semantic decision about when to use what. Accordingly, an entity is described by an element with child elements for its attributes in an instance XML document (see figure 2).

Optionality of attributes in the MIP IEDM is maintained by means of the XML Schema *minOccurs* attribute.

Non-key attributes are mapped to XML elements by applying the above-mentioned naming conventions. Whenever possible, the entity type name, which is added as a prefix for the attribute names in the logical view, is truncated. This rule conforms to the class and property conventions used in object-oriented programming, i.e., the meaning of an XML element is derived from its context.

Primary and foreign key attributes (i.e., identifiers and indexes) are not mapped directly. Instead, the transformation patterns for relationships (see next section) are applied.

Object Identifiers. In the WS/OO XSD, globally unique *object identifiers* (*OIDs*) replace the synthetic primary keys of the MIP data model. The global uniqueness of OIDs simplifies integration into object-oriented applications. An OID is a sequence of characters that allows an application locating and managing (persistent) objects. In the context of the world-wide web, an OID may be a URI (Uniform Resource Identifier). In this case, the OID denotes a web address that can be used to refer and retrieve the object, and the closure of all IEDM objects forms a localized semantic web of their own.

In the WS/OO XSD, OIDs are defined for all types that either correspond to independent entity types in the ER model or have list elements and thus need to be referable for future updates. Whether an XSD type has an OID is determined after applying the transformation patterns for relationships and associations.

References. At any place in an instance XML document where it is possible to specify an entity with an OID (inline), it is also possible to specify a reference to that entity. Both options are included (a) to provide support for various instance document styles, (b) to handle graph

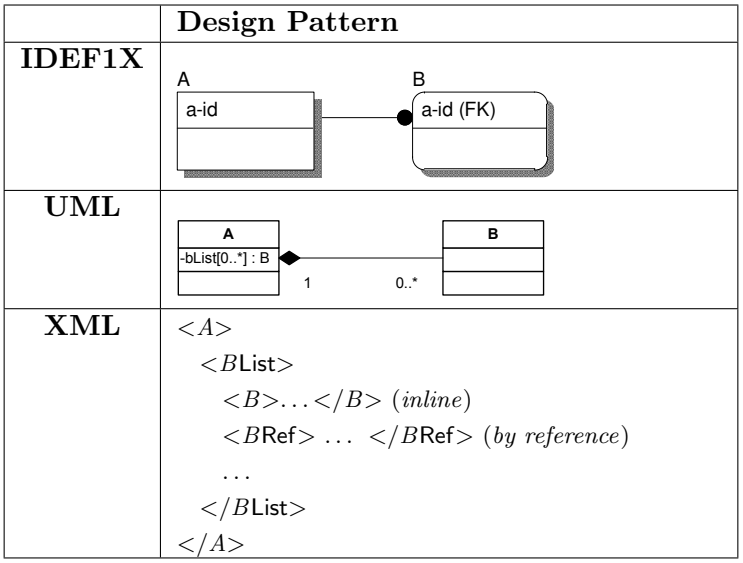


Figure 3: Identifying Relationships

structures, and (c) to allow for both referentially complete and incremental update information exchange methods.

References are indicated by adding suffix *Ref* to the name of the XML element (e.g., *UnitRef* or *ReportingOrganisationRef*). Beside its OID, an entity reference has neither elements (entity attributes) of simple type nor of code type. However, an entity reference can be used to describe a new relationship of the referred entity with another one. For instance, a new *OrganisationStatus* may be specified inside a *UnitRef* element (see next section for the modeling of relationships).

XML binding tools/frameworks like JAXB (Sun Developer Network, 2006), Castor (exolab.org, 2006), or Commons Betwixt (Jakarta Project, 2006) use XML's ID/IDREF mechanism to serialize graph structures. However, please note that ID/IDREF can only be used as a referencing mechanism for referentially complete documents but not when exchanging incremental updates.

The XML schema definition is available in two variants: with and without identity constraints, i.e., checks for internal referential completeness. The WS/OO XSD that includes the identity constraints enforces a corresponding entity definition for every reference. These entities must be defined by a child element of the root element. The identity constraints are specified in a way that ensures type-safe referential integrity of instance XML documents (ID/IDREF would not provide type-safety). The constraints are defined as part of the XML root element definition (see section 3.5).

3.4. Transformation Rules for Relationships

3.4.1. Identifying and Non-Identifying Relationships

In IDEF1X, the modeling technique and notation used for the MIP IEDM, there are two basic types of relationships: identifying and non-identifying relationships. They correspond to one-to-one and one-to-many associations between classes in UML where the associations may be navigable in either both directions or one direction. In most cases, a link is established from the parent to its child only.

An *identifying relationship* means that the child cannot be uniquely identified without the parent. For example, an *OBJECT-ITEM-STATUS* cannot exist without its *OBJECT-ITEM*. In an ER

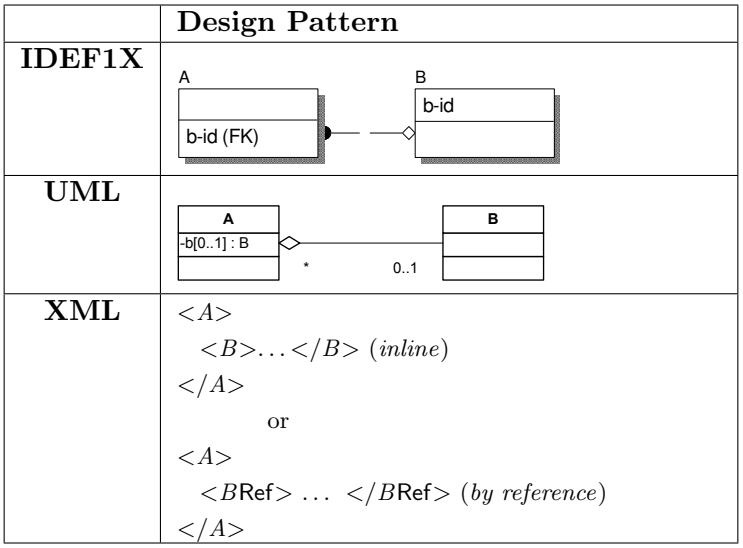


Figure 4: Non-Identifying Relationships

model, an identifying relationship is modeled by a primary key in the child that is also a foreign key referring to the parent.

Identifying relationships are modeled in the WS/OO XSD according to the design pattern shown in figure 3: A new list element, called *B*List, is embedded into the parent entity, which again encompasses multiple *B* elements. If possible, the name of the parent is stripped from the names of the elements. Example: The one-to-many relationship between an *OBJECT-ITEM* and an *OBJECT-ITEM-STATUS* is modeled in XML by *StatusList* and *Status* elements. (Note: strictly speaking *List* elements are not required but are included for clarity).

Depending on the cardinality of the relationship (zero-one-or-more, one-or-more, zero-or-one), the list element may be absent or contain one or more definitions of child entity *B*. The cardinality of identifying relationships is ensured by adding *minOccurs* and *maxOccurs* attributes to the corresponding definitions in the XSD.

Please note that *List* elements may also occur within entity references (e.g., within *ObjectItem-Ref*). This allows adding information on new relationships to entities that have been defined/exchanged before. In entity references, *minOccurs* is always set to 0.

A *non-identifying relationship* is one where the child can be identified independently of the parent. For instance, an *Organisation* can exist independently from a *ReportingData* that refers to it as the reporting organization. The transformation of non-identifying relationships is shown in figure 4. The optionality (null allowed vs. no null) of non-identifying relationships is expressed by *minOccurs* attributes in the WS/OO XSD.

3.4.2. Subtype Relationships

In instance XML documents, subtyping relationships are represented by embedding all the attributes from a subtype hierarchy within the tag corresponding to the leaf entity (see figure 5). In the WS/OO XML schema definition, the complex type for the sub-entity is derived from the complex type for the super entity by means of the *extension* method of XML Schema. Functional COIs may tailor individual types either by further extension or by restriction.

In IDEF1X, the subtype is indicated by a discriminator code (category code) in the super type. In WS/OO instance XML documents, category codes do not have to be specified in general, as

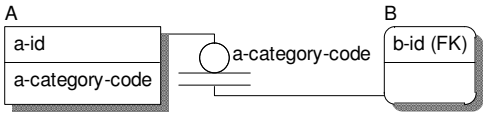
	Design Pattern
IDEF1X	
UML	
XML	<*B*> <*Attr*$_1$ *of A*>...</*Attr*$_1$ *of A*> <*Attr*$_2$ *of A*>...</*Attr*$_2$ *of A*> ... <*Attr*$_1$ *of B*>...</*Attr*$_1$ *of B*> ... </*B*>

Figure 5: Subtype Relationships

they are implied by the subtype tag itself. However, in the case of incomplete subtyping, the discriminator code must be specified if it does not correspond to one of the existing sub-entities (this holds for codes like *NOS – Not Otherwise Specified*).

3.4.3. Many-to-Many Relationships – Associative Entities

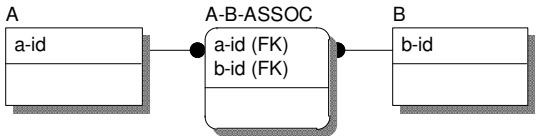
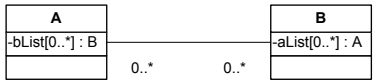
In relational models, a many-to-many relationship between two entities A and B is expressed by an associative entity *A-B-ASSOC* that is the child of both A and B via identifying relationships. In the MIP IEDM, all many-to-many-relationships are binary. Nevertheless, we can distinguish three cases:

- Associative entities with only primary key attributes
- Associative entities with non-primary key attributes
- Double-associative entities

An associative entity with only primary key (PK) attributes is equivalent in UML to a simple association between the two parent classes. Each parent may have a list of references to instances of the other class. This view is also reflected in the design pattern given in figure 6. Associative entities without non-PK attributes are not mapped onto the XML schema. The relationships from parent A to *A-B-ASSOC* and from parent B to *A-B-ASSOC* are mapped as if they were identifying relationships from A to B and vice versa. Note that since there is no preferred direction in the association, either entity can be nested inside the other in XML.

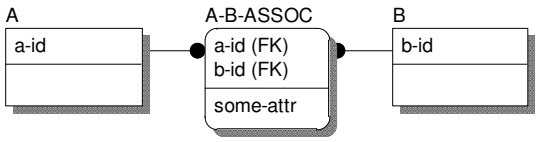
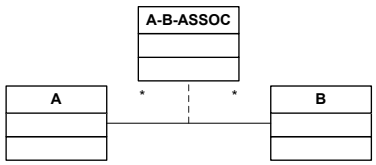
If the associative entity has non-primary key attributes, it corresponds in UML to an attributed association with an association class that contains the attributes. There are several ways to represent such many-to-many relationships in XML (see, e.g., Williams, 2002). For the WS/OO XSD, a design pattern is applied that allows embedding the association into either parent (see figure 7). For that purpose a list element (*ABAssoc*In*A*List) is introduced. It contains tuples consisting of the associated second parent of type B and the associative entity that holds the association attributes.

The ability to describe associations by nesting rather than by a top-level element avoids information scattering throughout XML documents and enhances readability. Moreover, the WS/OO

	Design Pattern
IDEF1X	
UML	

XML	$<A>$
	  $<B$List$>$
	  $<B>\ldots</B>$ $(inline)$
	  $<B$Ref$>\ldots</B$Ref$>$ $(by\ ref.)$
	  ...
	  $</B$List$>$
	$</A>$
	
	$<B>$
	  $<A$List$>$
	  $<A>\ldots</A>$ $(inline)$
	  $<A$Ref$>\ldots</A$Ref$>$ $(by\ ref.)$
	  ...
	  $</A$List$>$
	$</B>$

Figure 6: Associative Entities With Only PK Attributes

	Design Pattern
IDEF1X	
UML	

XML	$<A>$
	  $<ABAssoc$InAList$>$
	  $<ABAssoc$In$A>$
	  $<B>\ldots</B>$
	  $<ABAssoc>\ldots</ABAssoc>$
	  $</ABAssoc$In$A>$
	  $</ABAssoc$InAList$>$
	$</A>$
	
	$<ABAssoc>$
	  $<SomeAttr>$ ... $</SomeAttr>$
	  ...
	$</ABAssoc>$
	
	$<B>$
	  $<ABAssoc$InBList$>$
	  $<ABAssoc$In$B>$
	  $<A>\ldots</A>$
	  $<ABAssoc>\ldots</ABAssoc>$
	  $</ABAssoc$In$B>$
	  $</ABAssoc$InBList$>$
	$</A>$

Figure 7: Associative Entities With Non-PK Attributes

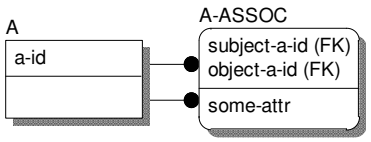
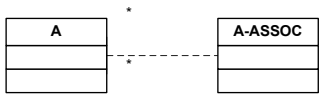
	Design Pattern
IDEF1X	
UML	
XML	<A> <AAssocInSubjectAList> <AAssocInSubjectA> <ObjectA>...</ObjectA> <AAssoc>...</AAssoc> </AAssocInSubjectA> </AAssocInSubjectAList> <AAssocInObjectAList> <AAssocInObjectA> <SubjectA>...</SubjectA> <AAssoc>...</AAssoc> </AAssocInObjectA> </AAssocInObjectAList> </A>

Figure 8: Double-Associative Entities

XSD supports object-to-association reasoning rather than association-to-object reasoning. This is considered as an important prerequisite for the compact definition of community-specific message formats that are derived from the generic XSD by tailoring.

It should be noted that the representation of associations in XML documents may differ from the internal representation in applications. For instance, the XML parser mentioned in section 5 generates Java objects that support navigability in either directions ($A \rightarrow ABAssoc \rightarrow B$ and $B \rightarrow ABAssoc \rightarrow A$).

There are also associations in which both relationships come from the same entity type. The generic syntactic transformations for such associations are similar to the transformations for associative entities with non-PK attributes given above. The only difference is that the element names include generic role names for the associated entities (see figure 8). *Subject* and *Object* are used as (model-independent) role names. The suffixes are necessary, because in an XML document the object may be embedded in the subject and vice versa.

3.5. XML Root Element

The root XML tag is equivalent to the model name in capital letters (<*JC3IEDM*>). The distinction between different model versions is made by means of the name space, whose URN, among others, incorporates the model version number.

The root XML element has an arbitrary number of unordered XML entity definitions as child elements. The names of the child elements are identical to the names of the corresponding entity types (e.g., *Unit* or *ReportingDataAbsoluteTiming*).

Each child must have a non-abstract and referable type. *Non-abstract* entity types do not have a subtype. For instance, *ObjectItem* is abstract whereas *MinefieldLand* is not. (In case of incomplete subtyping, the super type can be regarded as non-abstract as well). *Referable* entity types have an *object identifier* (*OID*) attribute. An instance XML document with five top-level entity definitions is shown in listing 1 on page 15.

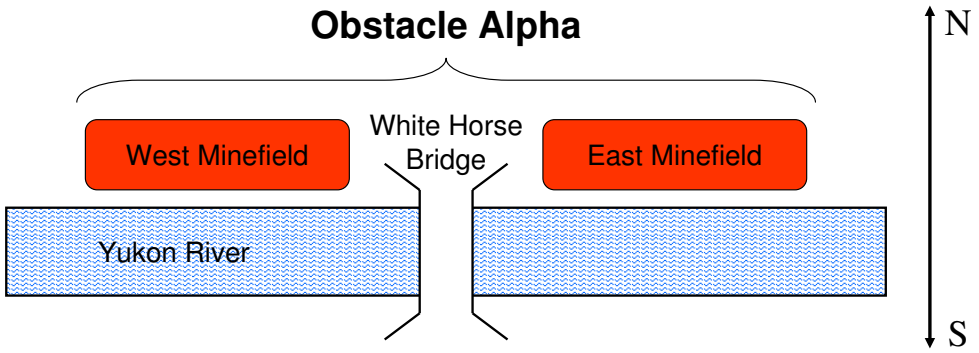


Figure 9: Obstacle Alpha

4. XML Example

In the following, the use of the object-oriented XML schema is illustrated by the operational scenario described in chapter 9.6 of the JC3IEDM main document (MIP, 2005, p. 246). For convenience, it is recapitulated in section 4.1. The modeling of the vignette by means of the JC3IEDM is described in section 4.2. Excerpts from the corresponding instance XML documents are explained in section 4.3. For the complete documents, please see appendix A.

4.1. Operational Scenario

The JC3IEDM main document defines an operational scenario in which the 1st Canadian Brigade is located near a bridge across the Yukon River. Its contingency plan is to use this bridge as part of a larger military obstacle, called *Obstacle Alpha*:

> "The White Horse Bridge across the Yukon River initially serves as a passage between two minefields located on the north side of the river, one on each side of the bridge. [...] If the units of the joint task force that are now deployed on the north side of the river need to withdraw, the bridge will be demolished to become part of the main obstacle." (MIP, 2005, p. 246)

The operational picture is shown in figure 9.

During the hostilities, the 1st CA Brigade is attacked and the contingency plan is put into action. The complete course of actions is as follows:

Reporting Time	**Action**
22 Oct 2003, 10:30	1 CA Brigade creates the contingency plan to set up Obstacle Alpha which consists of the two minefields and the bridge to be demolished.
02 Nov 2003, 09:49	Minefield West is laid and activated.
03 Nov 2003, 15:42	Minefield East is laid and activated.
03 Nov 2003, 17:10	The White Horse Bridge is prepared for demolition.
07 Nov 2003, 08:10	The brigade elements north of the river cross to the south. The bridge is demolished and Obstacle Alpha becomes operational in its entirety.

4.2. JC3IEDM Modeling

In the JC3IEDM, the two minefields are modeled by means of entity type *MINEFIELD-LAND*. The White Horse Bridge is an instance of entity type *BRIDGE* and Obstacle Alpha is a *MILITARY-OBSTACLE*.

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3
    ..\..\schema\JC3IEDMSchemaWithConstraints.xsd">
  <MinefieldLand>
    <OID>OI1</OID>
    <NameText>West Minefield</NameText>
    ...
    <LengthDimension>300</LengthDimension>
    <WidthDimension>105</WidthDimension>
    <IdentificationText>Minefield West</IdentificationText>
    <MineSpacingDimension>10</MineSpacingDimension>
    <DepthPlacementCode>MIXED</DepthPlacementCode>
    <FunctionCode>NUISNC</FunctionCode>
    <PatternCode>REGTHK</PatternCode>
    <PersistenceCode>REMOTE</PersistenceCode>
    <StoppingPowerCode>MEDIUM</StoppingPowerCode>
  </MinefieldLand>
  <MinefieldLand>
    <OID>OI2</OID>
    <NameText>East Minefield</NameText>
    ...
  </MinefieldLand>
  <Bridge>
    <OID>OI3</OID>
    <NameText>White Horse Bridge</NameText>
    ...
  </Bridge>
  <MilitaryObstacle>
    <OID>OI4</OID>
    <NameText>Obstacle Alpha</NameText>
    ...
  </MilitaryObstacle>
  <ReportingDataAbsoluteTiming>
    <OID>RPTD705</OID>
    ...
  </ReportingDataAbsoluteTiming>
  ...
</JC3IEDM>
```

Listing 1: Top-level elements

Since all entities are facilities, their statuses are described by means of entity type *FACILITY-STATUS*. Both the White Horse Bridge and Obstacle Alpha have two status objects assigned to them, because their statuses change over time. Initially, the bridge is operational and prepared for plan execution while Obstacle Alpha is merely planned. Once White Horse Bridge is demolished, Obstacle Alpha is declared as operational and active. All status information is associated with either a *REPORTING-DATA* or a *REPORTING-DATA-ABSOLUTE-TIMING*. The composition of Obstacle Alpha is modeled by instances of *OBJECT-ITEM-ASSOCIATION* and *OBJECT-ITEM-ASSOCIATION-STATUS*.

The overall data structure for the vignette is given as a UML object diagram in appendix A.1 on page 23. The granularity and expressive richness of the JC3IEDM can be seen by this example. The symbol colors indicate the different times of creation of the corresponding objects. In total, the vignette is modeled by 41 objects. With a JC3IEDM-compliant RDBMS, the effective number of database records would be significantly higher, since, e.g., the information for a land minefield is physically stored in five different tables (*OBJECT-ITEM*, *FACILITY*, *MILITARY-OBSTACLE*, *MINEFIELD*, and *MINEFIELD-LAND*).

```
1  <MinefieldLand>
2    <OID>OI1</OID>
3    <NameText>West Minefield</NameText>
4    <ObjectItemTypeInObjectItemList>
5      <ObjectItemTypeInObjectItem>
6        <ObjectTypeRef>
7          <OID>OT1</OID>
8        </ObjectTypeRef>
9        <ObjectItemType>
10         <ReportingDataRef>
11           <OID>RPTD001</OID>
12         </ReportingDataRef>
13       </ObjectItemType>
14     </ObjectItemTypeInObjectItem>
15   </ObjectItemTypeInObjectItemList>
16   <StatusList>
17     <Status xsi:type="FacilityStatus">
18       <HostilityCode>FR</HostilityCode>
19       <ReportingData xsi:type="ReportingDataAbsoluteTiming">
20         <OID>RPTD701</OID>
21         <CategoryCode>REP</CategoryCode>
22         <CredibilityCode>RPTFCT</CredibilityCode>
23         <ReportingDatetime>20031102094900.000</ReportingDatetime>
24         ...
25       </ReportingData>
26       <MinePresenceCode>YES</MinePresenceCode>
27       <OperationalStatusCode>OPR</OperationalStatusCode>
28       <UsageStatusCode>ACTIVE</UsageStatusCode>
29       <CategoryCode>NOS</CategoryCode>
30     </Status>
31   </StatusList>
32   <LengthDimension>300</LengthDimension>
33   <WidthDimension>105</WidthDimension>
34   ...
35 </MinefieldLand>
```

Listing 2: Status information

4.3. Instance XML Documents

The overall structure of an XML document for the above-mentioned vignette is shown in listing 1. It is a referentially complete document that covers the whole history of Obstacle Alpha.

On the top level, the main objects of the operational scenario, i.e., West Minefield, East Minefield, White Horse Bridge, Obstacle Alpha, etc. are defined. Each object is described coherently by a single element rather than by records in multiple tables as when using the MIP DEM. For instance, all attributes of a *MinefieldLand* – including those inherited from entity types *Facility* and *ObjectItem* – are specified at a single place in the document (lines 3–16).

All objects shown above have a globally unique object identifier (OID). This allows referring to them from a different object in the same XML document or from another XML document in order to establish an association.

In the previous excerpt, only the basic attributes were listed for the West Minefield. In reality, its definition also includes a status and a type. In the JC3IEDM ER model, they are linked to the minefield by means of identifying relationships and associative entities. Their modeling in XML is illustrated in listing 2. Since a *MinefieldLand* can have multiple statuses (one-to-zero-one-or-more relationship), the status is wrapped in a *StatusList* element that may contain an arbitrary number of status definitions (lines 16–31). The relationship between the West Minefield and its status is established by embedding the latter into the definition of the former. By means of nesting, it is not necessary to specify the OID of the West Minefield within the status definition as required by the JC3IEDM ER model – the link between both entities is derived implicitly from the document structure.

```
1  <MinefieldLand>
2    <OID>OI1</OID>
3    <NameText>West Minefield</NameText>
4    ...
5    <StatusList>
6      <Status xsi:type="FacilityStatus">
7        <HostilityCode>FR</HostilityCode>
8        <ReportingData xsi:type="ReportingDataAbsoluteTiming">
9          <OID>RPTD701</OID>
10         ...
11         <ReportingOrganisationRef>
12           <OID>OI6</OID>
13         </ReportingOrganisationRef>
14         ...
15       </ReportingData>
16       ...
17     </Status>
18   </StatusList>
19   ...
20 </MinefieldLand>
21 <Unit>
22   <OID>OI6</OID>
23   <NameText>1 CA Bde</NameText>
24   ...
25   <FormalAbbreviatedNameText>1 CA Bde</FormalAbbreviatedNameText>
26 </Unit>
```

Listing 3: References

Listing 2 also shows that not all elements have an OID. Unlike the minefield, the minefield status is not referable. Whereas the minefield may get a new status later and thus there must be a way to refer to it, the status object itself cannot be changed in the future. In general, only those entities to which information may be added later have an OID. Among others, the 15 independent entity types of the JC3IEDM (including their sub-entity types) and associations whose status is subject to change have an OID attribute.

Finally, listing 2 illustrates the application of the polymorphism concept. According to the JC3IEDM entity-relationship model (disregarding business rules), an object item can be associated with any record of the status hierarchy, e.g., a *FacilityStatus*, a *MedicalFacilityStatus*, or a *PersonStatus*. Similarly, we can refer to different kinds of *ReportingData* (*ReportingData*, *ReportingDataAbsoluteTiming*, *ReportingDataRelativeTiming*) within a status. In order to support document validation, one has to specify the concrete type that is actually used. This is done by means of attribute *xsi:type* (XSI = XML Schema Instance). For instance, in line 19, we specify *xsi:type="ReportingDataAbsoluteTiming"* to define a ReportingData with absolute timing information.

Nesting of entities is not restricted to a certain level. In listing 2, *ReportingData* is embedded in the *Status* element, which again is part of the West Minefield definition. In principle, structures may become very deeply nested or – in case of cyclic dependencies between objects – even infinitely. In these cases, the reference mechanism can be used which is revealed in listing 3.[4]

For every status update, the reporting organization must be specified as part of the reporting data. The status of the West Minefield is reported by the 1st Canadian Brigade. Rather than embedding the *ReportingOrganisation* inside the *MinefieldLand*/*StatusList*/*Status*/*ReportingData* structure, a reference is made by means of a *ReportingOrganisationRef* element (lines 11–13) that only contains the OID of the organization to which it refers. The unit is defined as a separate top-level element in the XML document (lines 21–26). In case of a reference, there is

[4]If for some arbitrary reason communities choose to avoid deep nesting in all cases, this can be accomplished through functional community business rules applied at the namespace or specific business object level.

```
1  <?xml version="1.0" encoding="UTF-8"?>
2  <JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
       xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
3    <MinefieldLandRef>
4      <OID>OI1</OID>
5      <StatusList>
6        <Status xsi:type="FacilityStatus">
7          <HostilityCode>FR</HostilityCode>
8          <ReportingData xsi:type="ReportingDataAbsoluteTiming">
9            ...
10         </ReportingData>
11         <MinePresenceCode>YES</MinePresenceCode>
12         <OperationalStatusCode>OPR</OperationalStatusCode>
13         <UsageStatusCode>ACTIVE</UsageStatusCode>
14         <CategoryCode>NOS</CategoryCode>
15       </Status>
16     </StatusList>
17   </MinefieldLandRef>
18 </JC3IEDM>
```

Listing 4: Incremental update

no need to specify the concrete subtype. In the example above, no *xsi:type* attribute is required in line 11, although the *ReportingOrganisationRef* is in fact a reference to a *Unit*. In the given example, the 1st CA Bde is specified at the end of the XML document. However, the XML schema makes no assumptions on the order of top-level elements, i.e., an object may be defined ahead of its reference.

As explained in section 2.2, there are several possible ways in which communication may take place. The generic WS/OO XML schema is designed in a way that it can be used in all scenarios described above. In message-based communication, the constraints in the WS/OO XSD ensure referential integrity within a single XML document: whenever a reference is made, a corresponding definition must be given. For instance, an XSD validation tool is able to check that there is indeed a reporting organization for the minefield status. The corresponding constraints are type-safe, i.e., the schema validator will complain if you refer to a non-Organization object accidentally.

For incremental updates and incomplete queries, the referencing mechanism can be used to refer to information defined externally. This is illustrated in listing 4. In this document, a status update is reported for the object with OID *OI1* (= West Minefield). In addition to an OID, an *<Entity>Ref* element may contain an arbitrary number of list elements. In that way, you can establish new associations with existing objects.

5. Tool Support

A tool set has been developed to support the generation and application of the WS/OO XSD. The software, which was developed at the Research Institute for Communication, Information Processing and Ergonomics, FGAN FKIE, Germany, comprises the following components:

- A combined WS/OO schema and Java source code generator.
- A set of model-independent Java base classes that complement the Java class library.
- An XML parser that processes (unmarshalls) instance XML documents.
- Supplementary tools for validating and pretty-printing XML documents.

The toolkit is based on the Java 5.0 specification and provided as an Eclipse 3.1 project (Eclipse Foundation, 2006).

The XML schema and Java code generation is carried out in three steps:

1. The MIP IEDM meta model is read from a file in ERwin XML format and stored in an internal data structure.[5]
2. Various automated transformations are applied to the meta model in order to realize the design patterns described in section 3. Among others, these transformations include the removal of key attributes, the selective addition of OID attributes, and the introduction of list attributes for identifying relationships.
3. Based on the modified meta model, two different outputs are produced:

   Modular WS/OO XSD — It is provided as five files that contain the schema definitions for the entities, codes, and simple types of the MIP IEDM, as well as the definition of the XML root element (with and without identity constraints that ensure referential integrity). The physical partition of the XSD improves maintenance, design, and reuse. The XSD is available in two versions: a schema definition with annotations (i.e., additional comments) and a stripped-down version for more efficient processing.

   Java class library — It consists of a large number of class files that are grouped into three packages (*entity*, *code*, and *simple*). The Java classes are structurally equivalent to the type definitions in the XSD with the exception of associations that are represented differently to support navigation in both directions (from subject to object and vice versa).

To demonstrate that MIP WS/OO instance documents can be validated and processed efficiently, we developed an XML parser that reads data in XML and creates and initializes corresponding Java objects.

The parser is based on the *Simple API for XML* (SAX), which is a component of the *Java API for XML Processing* (*JAXP*; Sun Microsystems, 2006). SAX parsing is event-driven: whenever an XML element begins or ends, a corresponding callback function is invoked. Unlike the DOM (Document Object Model), SAX allows reading XML documents incrementally (stream processing). This means that there is no need to keep the complete XML document in memory. In order to process WS/OO instance documents, it is sufficient to maintain an information stack whose size increases and decreases with varying nesting level of XML elements.

The XML parser is generic in that it does not require meta model information. Object creation and manipulation is based on the Java reflection mechanism that allows calling methods *by name* at run-time. The core of the XML parser comprises about 250 lines of code. To simplify processing, the parser makes use of some fixed attributes by which XML documents are enriched during schema validation. For instance, any *<Entity>List* element has a *typeCategoryCode* attribute with fixed value *AssociationList*. Fixed attributes make it possible to identify elements that describe entities, associations, and lists without having to rely on tag naming conventions or meta model information. The MIP WS/OO XSD already comes along with specifications for various fixed attributes. Additional fixed attributes might further simplify the processing of associations. Developers are free to introduce such attributes in the MIP XSD for internal purposes, as long as the attributes do not show up in exchanged instance documents.

The development of the parser has proven that the potentially deep nesting of XML elements does not impose any technical burden and – given a suitable internal object representation –

[5] The generator tool expects XML output of ERwin 4.1.4 Service Pack 3 (i.e., version 4.1.4.4224), the version of Computer Associate's data modeling tool that is used by the MIP. Unfortunately, the ERwin XML format is not stable. We noticed that it changed even with service packs.

the referencing mechanism can be handled in a simple way. Processing of associations also proved to be unproblematic even though their representation in XML documents differs from the representation in the Java classes (where links are introduced from the associating entity to the associated objects).

The XML parser also demonstrates that incremental updates can be handled easily. For instance, reading the referentially complete XML document in appendix A.2 results in the same internal Java object representation as consecutively loading all partial XML documents from appendix A.3.

The tools and the XML/Java products that they generate are available at the MIP homepage (MIP, 2006). They are provided under the Berkeley Software Distribution (BSD) license (Wikipedia, 2006a), i.e., they can be used freely in both non-commercial and commercial projects.

6. Summary and Conclusion

In this paper, we have presented the reference MIP WS/OO XSD that is conformant with the logical model of the JC3IEDM. The MIP IEDM is driven by a C2 Community of Interest and provides a system-independent view of information exchange requirements. Likewise, the WS/OO XSD provides a system-neutral representation suited for exchange.

The WS/OO XSD is designed in a way that it is extensible by other functional communities. All functional communities (surveillance, logistics, fires, anti-submarine warfare, artillery, modeling and simulation, testing, etc.) semantically overlap command and control. Thus extending the C2 logical model (and XSD) as required with community unique concepts and semantics ensures that all functional commanders and processes can receive and understand the commander's intent and provide feedback as required. Technically, extensions can be made in two ways: by complementing the XSD with manually defined complex types (possibly derived from existing types) or by extending the MIP ER model and re-running the XSD generation tool.

The XML schema and its accompanying products described in this paper present a reference baseline suitable for supporting a broad scope of XML application and service development work. Currently, XML schemas are available for both the JC3IEDM 3.0 and the C2IEDM 6.15e. They are being published in the public space to encourage use of the MIP IEDM semantics and to serve as a catalyst for MIP capability development using XML. MIP also intends to make submissions to the forthcoming NATO XML Registry. The explicit purpose of MIP continuing with the development of XML reference capabilities is not to replace or dictate national development efforts, but rather, to significantly lower the barrier for those interested in learning and implement MIP-capable XML services and applications.

The WS/OO XSD satisfies the needs of various information exchange mechanisms. Semantic checks for valid domain values, optional/mandatory attributes, and document consistency allow thorough validation before processing the data. With the JC3IEDM as a sound semantic foundation, the XML schema builds a bridge between message-based and replication-based information exchanges.

Areas of future work include the formal representation of JC3IEDM business rules. For instance, the XSD does not check for legal code combinations. Unfortunately, the expressiveness of XML Schema is too limited to describe such business rules. A language which focuses on the specification of semantic checks is Schematron (see ISO/IEC, 2004). Unlike XML Schema, which is used to describe the structure of XML documents, Schematron follows a rule-based approach. It can be used as a supplement to XML Schema.

References

Eclipse Foundation (2006). Eclipse Software Development Kit. `http://www.eclipse.org/`. 19

exolab.org (2006). Castor – Open Source data binding framework for Java. `http://www.castor.org/`. 9

ISO – International Organization for Standardization (2005). ISO/TS 15000-5:2005 Electronic Business Extensible Markup Language (ebXML) – Part 5: ebXML Core Components Technical Specification, Version 2.01 (ebCCTS). Available through the ISO store at `http://www.iso.org/`. Also available for free as UN/CEFACT CCTS V2.01 (`http://www.unece.org/cefact/ebxml/CCTS_V2-01_Final.pdf`). 6

ISO/IEC – International Organization for Standardization/International Electrotechnical Commission (2004). ISO/IEC FDIS 19757-3, Rule-based validation – Schematron. `http://www.schematron.org`. 20

ISO/IEC – International Organization for Standardization/International Electrotechnical Commission (2005). ISO/IEC 11179, Information Technology – Metadata Registries (MDR). All ISO/IEC 11179 standards are available for free at `http://metadata-standards.org/`. 6

Jakarta Project (2006). Commons Betwixt – Turning beans into XML. `http://jakarta.apache.org/commons/betwixt/index.html`. 9

MIP – Multilateral Interoperability Programme (2005). The Joint C3 Information Exchange Data Model (JC3IEDM Main), Edition 3.0. `http://www.mip-site.org`. 1, 14

MIP – Multilateral Interoperability Programme (2006). MIP Home Page. `http://www.mip-site.org/`. 20

Sun Developer Network (2006). Java Architecture for XML Binding (JAXB). `http://java.sun.com/webservices/jaxb/`. 9

Sun Microsystems (2006). Java API for XML Processing (JAXP) 1.3. `http://java.sun.com/webservices/jaxp/index.jsp`. 19

van der Vlist, E. (2001). Comparing XML Schema Languages. O'Reilly xml.com, `http://www.xml.com/pub/a/2001/12/12/schemacompare.html`. 5

W3C (2004a). XML Schema Part 0: Primer Second Edition. W3C Recommendation. `http://www.w3.org/TR/2004/REC-xmlschema-0-20041028/`. 5

W3C (2004b). XML Schema Part 1: Structures Second Edition. W3C Recommendation. `http://www.w3.org/TR/2004/REC-xmlschema-1-20041028/`. 5

W3C (2004c). XML Schema Part 2: Datatypes Second Edition. W3C Recommendation. `http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/`. 5

Wikipedia (2006a). BSD license. Wikipedia, the free encyclopedia, `http://en.wikipedia.org/wiki/BSD_license`. 20

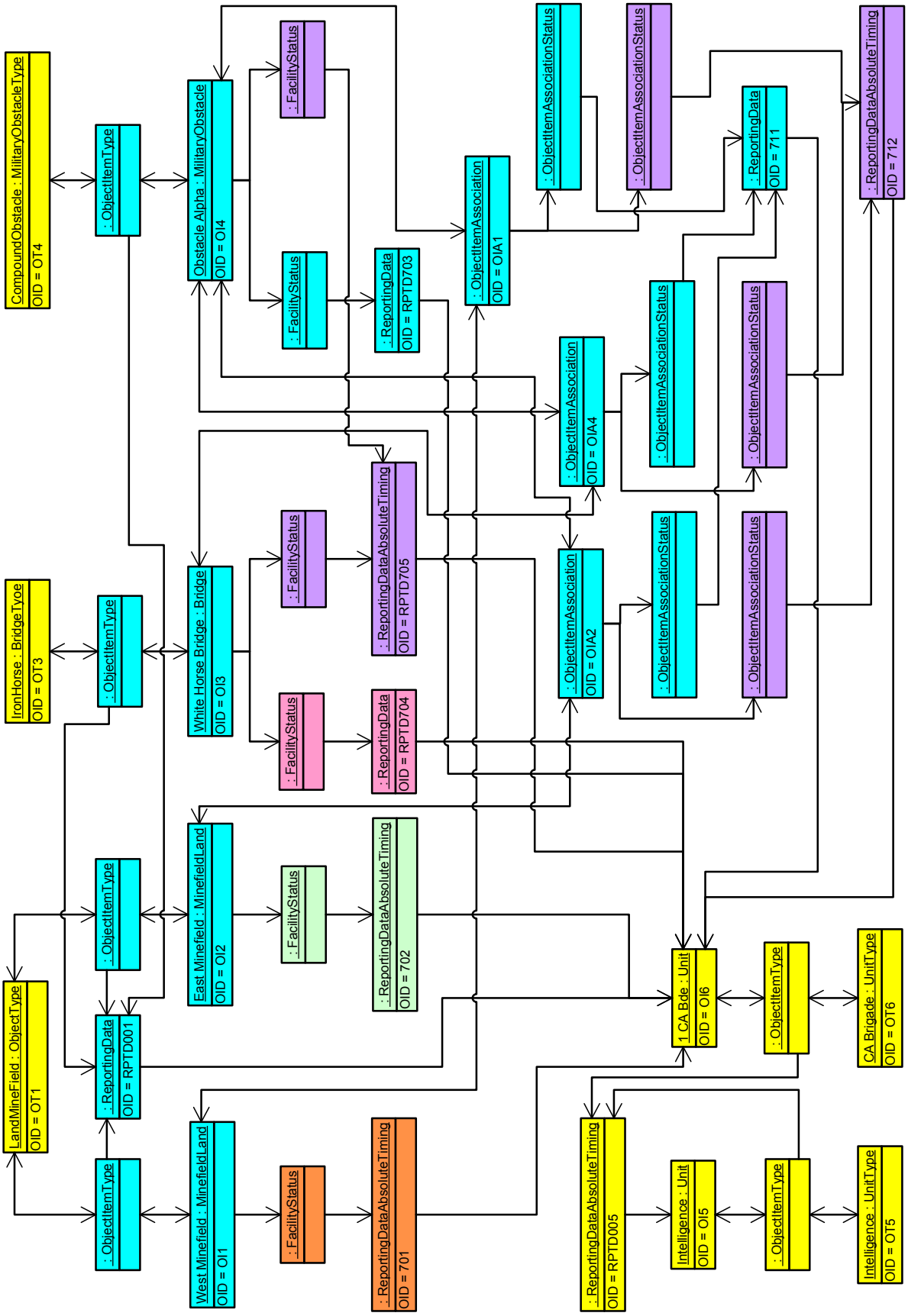
Wikipedia (2006b). ICAM Definition Languages (IDEF). Wikipedia, the free encyclopedia, `http://en.wikipedia.org/wiki/IDEF`. 6

Williams, K. (2002). XML for Data: Modeling many-to-many relationships. IBM developerWorks, `http://www-128.ibm.com/developerworks/xml/library/x-xdm2m.html`. 11

A. XML Example – Obstacle Alpha

In this appendix, the complete instance XML documents are presented for the vignette described in section 4 on page 14. The formal specification of the operational scenario by means of the JC3IEDM is shown in section A.1. The XML document in section A.2 describes the complete history of the operational scenario. The documents in section A.3 illustrate replication-based information exchange with incremental updates.

A.1. JC3IEDM Model



A.2. Referentially Complete Document

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3␣
    ..\..\schema\JC3IEDMSchemaWithConstraints.xsd">
  <!--
    9.6 Example of Using a Facility as Part of an Obstacle

    9.6.1 The White Horse Bridge across the Yukon River initially serves as a passage between two minefields
        located on the north side of the river, one on each side of the bridge. The contingency plan is to use the
        bridge as part of an obstacle. If the units of the joint task force that are now deployed on the north side
        of the river need to withdraw, the bridge will be demolished to become part of the main obstacle. The
        general layout is illustrated in Figure 72 where North is toward top of the page.

    9.6.2 The sequence of events is as follows:
      a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
          of three components: two minefields and a demolished bridge.
      b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
      c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
      d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
          Obstacle Alpha becomes operational in its entirety.
  -->
  <MinefieldLand>
    <OID>OI1</OID>
    <NameText>West Minefield</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT1</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingData xsi:type="ReportingDataAbsoluteTiming">
          <OID>RPTD701</OID>
          <CategoryCode>REP</CategoryCode>
          <CredibilityCode>RPTFCT</CredibilityCode>
          <ReportingDatetime>20031102094900.000</ReportingDatetime>
          <ReportingOrganisationRef>
            <OID>OI6</OID>
          </ReportingOrganisationRef>
          <EffectiveStartDatetime>20031102094500.000</EffectiveStartDatetime>
        </ReportingData>
        <MinePresenceCode>YES</MinePresenceCode>
        <OperationalStatusCode>OPR</OperationalStatusCode>
        <UsageStatusCode>ACTIVE</UsageStatusCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
    <LengthDimension>300</LengthDimension>
    <WidthDimension>105</WidthDimension>
    <IdentificationText>Minefield West</IdentificationText>
    <MineSpacingDimension>10</MineSpacingDimension>
    <DepthPlacementCode>MIXED</DepthPlacementCode>
    <FunctionCode>NUISNC</FunctionCode>
    <PatternCode>REGTHK</PatternCode>
    <PersistenceCode>REMOTE</PersistenceCode>
    <StoppingPowerCode>MEDIUM</StoppingPowerCode>
  </MinefieldLand>
  <MinefieldLand>
    <OID>OI2</OID>
```

```
    <NameText>East Minefield</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT1</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingData xsi:type="ReportingDataAbsoluteTiming">
          <OID>RPTD702</OID>
          <CategoryCode>REP</CategoryCode>
          <CredibilityCode>RPTFCT</CredibilityCode>
          <ReportingDatetime>20031103154200.000</ReportingDatetime>
          <ReportingOrganisationRef>
            <OID>OI6</OID>
          </ReportingOrganisationRef>
          <EffectiveStartDatetime>20031103153000.000</EffectiveStartDatetime>
        </ReportingData>
        <MinePresenceCode>YES</MinePresenceCode>
        <OperationalStatusCode>OPR</OperationalStatusCode>
        <UsageStatusCode>ACTIVE</UsageStatusCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
    <LengthDimension>320</LengthDimension>
    <WidthDimension>90</WidthDimension>
    <IdentificationText>Minefield East</IdentificationText>
    <MineSpacingDimension>10</MineSpacingDimension>
    <DepthPlacementCode>MIXED</DepthPlacementCode>
    <FunctionCode>NUISNC</FunctionCode>
    <PatternCode>REGTHK</PatternCode>
    <PersistenceCode>REMOTE</PersistenceCode>
    <StoppingPowerCode>MEDIUM</StoppingPowerCode>
  </MinefieldLand>
  <Bridge>
    <OID>OI3</OID>
    <NameText>White Horse Bridge</NameText>
    <!-- the following tag provides additional information on typing -->
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT3</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingData xsi:type="ReportingData">
          <OID>RPTD704</OID>
          <CategoryCode>REP</CategoryCode>
          <CredibilityCode>RPTFCT</CredibilityCode>
          <ReportingDatetime>20031103171000.000</ReportingDatetime>
          <ReportingOrganisationRef>
            <OID>OI6</OID>
          </ReportingOrganisationRef>
          <TimingCategoryCode>TIMNA</TimingCategoryCode>
```

```
        </ReportingData>
        <DemolitionStatusCode>PRPEXE</DemolitionStatusCode>
        <MinePresenceCode>NO</MinePresenceCode>
        <OperationalStatusCode>OPR</OperationalStatusCode>
        <OperationalStatusQualifierCode>PASABL</OperationalStatusQualifierCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingDataRef>
          <OID>RPTD705</OID>
        </ReportingDataRef>
        <DemolitionStatusCode>EXECTD</DemolitionStatusCode>
        <MinePresenceCode>NO</MinePresenceCode>
        <OperationalStatusCode>NOP</OperationalStatusCode>
        <OperationalStatusQualifierCode>DSTRYD</OperationalStatusQualifierCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
    <LengthDimension>200</LengthDimension>
    <WidthDimension>10</WidthDimension>
    <LongestSpanLengthDimension>40</LongestSpanLengthDimension>
    <SpanCount>5</SpanCount>
    <UsageCode>RLWYVH</UsageCode>
  </Bridge>
  <MilitaryObstacle>
    <OID>OI4</OID>
    <NameText>Obstacle Alpha</NameText>
    <ObjectItemAssociationInObjectObjectItemList>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI1</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociation>
          <OID>OIA1</OID>
          <CategoryCode>ISPART</CategoryCode>
          <StatusList>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD711</OID>
              </ReportingDataRef>
            </Status>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD712</OID>
              </ReportingDataRef>
            </Status>
          </StatusList>
        </ObjectItemAssociation>
      </ObjectItemAssociationInObjectObjectItem>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI2</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociation>
          <OID>OIA2</OID>
          <CategoryCode>ISPART</CategoryCode>
          <StatusList>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD711</OID>
              </ReportingDataRef>
            </Status>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD712</OID>
```

```
            </ReportingDataRef>
          </Status>
        </StatusList>
      </ObjectItemAssociation>
    </ObjectItemAssociationInObjectObjectItem>
    <ObjectItemAssociationInObjectObjectItem>
      <SubjectObjectItemRef>
        <OID>OI3</OID>
      </SubjectObjectItemRef>
      <ObjectItemAssociation>
        <OID>OIA4</OID>
        <CategoryCode>ISPART</CategoryCode>
        <StatusList>
          <Status>
            <CategoryCode>START</CategoryCode>
            <ReportingDataRef>
              <OID>RPTD711</OID>
            </ReportingDataRef>
          </Status>
          <Status>
            <CategoryCode>START</CategoryCode>
            <ReportingDataRef>
              <OID>RPTD712</OID>
            </ReportingDataRef>
          </Status>
        </StatusList>
      </ObjectItemAssociation>
    </ObjectItemAssociationInObjectObjectItem>
  </ObjectItemAssociationInObjectObjectItemList>
  <ObjectItemTypeInObjectItemList>
    <ObjectItemTypeInObjectItem>
      <ObjectTypeRef>
        <OID>OT4</OID>
      </ObjectTypeRef>
      <ObjectItemType>
        <ReportingDataRef>
          <OID>RPTD001</OID>
        </ReportingDataRef>
      </ObjectItemType>
    </ObjectItemTypeInObjectItem>
  </ObjectItemTypeInObjectItemList>
  <StatusList>
    <Status xsi:type="FacilityStatus">
      <HostilityCode>FR</HostilityCode>
      <ReportingData xsi:type="ReportingData">
        <OID>RPTD703</OID>
        <CategoryCode>PLAN</CategoryCode>
        <CredibilityCode>RPTFCT</CredibilityCode>
        <ReportingDatetime>20031022103000.000</ReportingDatetime>
        <ReportingOrganisationRef>
          <OID>OI6</OID>
        </ReportingOrganisationRef>
        <TimingCategoryCode>TIMNA</TimingCategoryCode>
      </ReportingData>
      <MinePresenceCode>YES</MinePresenceCode>
      <OperationalStatusCode>NOP</OperationalStatusCode>
      <OperationalStatusQualifierCode>PRPEXE</OperationalStatusQualifierCode>
      <CategoryCode>NOS</CategoryCode>
    </Status>
    <Status xsi:type="FacilityStatus">
      <HostilityCode>FR</HostilityCode>
      <ReportingDataRef>
        <OID>RPTD705</OID>
      </ReportingDataRef>
      <MinePresenceCode>YES</MinePresenceCode>
      <OperationalStatusCode>OPR</OperationalStatusCode>
      <UsageStatusCode>ACTIVE</UsageStatusCode>
      <CategoryCode>NOS</CategoryCode>
    </Status>
  </StatusList>
```

```
    <LengthDimension>650</LengthDimension>
    <WidthDimension>325</WidthDimension>
    <CategoryCode>NOS</CategoryCode>
  </MilitaryObstacle>
  <ReportingDataAbsoluteTiming>
    <OID>RPTD705</OID>
    <CategoryCode>REP</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031107081000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20031107080000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
  <ReportingData>
    <OID>RPTD711</OID>
    <CategoryCode>PLAN</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031022103000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <TimingCategoryCode>TIMNA</TimingCategoryCode>
  </ReportingData>
  <ReportingDataAbsoluteTiming>
    <OID>RPTD712</OID>
    <CategoryCode>REP</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031107081000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20031107080000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
  <!--
        the following content provides reference information required to complete the example
    -->
  <MilitaryObstacleType>
    <!-- MilitaryObstacleType of the minefields -->
    <OID>OT1</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>LandMinefield</NameText>
    <CategoryCode>MINEFD</CategoryCode>
  </MilitaryObstacleType>
  <BridgeType>
    <!-- BridgeType for White Horse Bridge -->
    <OID>OT3</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>Iron Horse</NameText>
    <DesignTypeCode>CNTLVR</DesignTypeCode>
  </BridgeType>
  <MilitaryObstacleType>
    <!-- MilitaryObstacleType of Obstacle Alpha -->
    <OID>OT4</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>Compound obstacle</NameText>
    <CategoryCode>NOS</CategoryCode>
  </MilitaryObstacleType>
  <ReportingData>
    <!-- ReportingData for associating Obstacle Alpha and its components with their types -->
    <OID>RPTD001</OID>
    <CategoryCode>REP</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031022103000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <TimingCategoryCode>TIMNA</TimingCategoryCode>
  </ReportingData>
  <Unit>
```

```
    <!-- Unit that is reporting its activities -->
    <OID>OI6</OID>
    <NameText>1 CA Bde</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectType xsi:type="UnitType">
          <OID>OT6</OID>
          <DummyIndicatorCode>NO</DummyIndicatorCode>
          <NameText>CA Brigade</NameText>
          <CommandFunctionIndicatorCode>YES</CommandFunctionIndicatorCode>
          <ServiceCode>ARMY</ServiceCode>
          <CategoryCode>COMBAT</CategoryCode>
          <ArmCategoryCode>INF</ArmCategoryCode>
          <SizeCode>BDE</SizeCode>
        </ObjectType>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD005</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <FormalAbbreviatedNameText>1 CA Bde</FormalAbbreviatedNameText>
  </Unit>
  <Unit>
    <!-- Unit that first recorded the White Horse Bridge -->
    <OID>OI5</OID>
    <NameText>Intelligence</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectType xsi:type="UnitType">
          <OID>OT5</OID>
          <DummyIndicatorCode>NO</DummyIndicatorCode>
          <NameText>Intelligence</NameText>
          <CommandFunctionIndicatorCode>NO</CommandFunctionIndicatorCode>
          <ServiceCode>JOINT</ServiceCode>
          <!-- check category code -->
          <CategoryCode>COMSPT</CategoryCode>
          <ArmCategoryCode>MILINT</ArmCategoryCode>
          <SizeCode>BDE</SizeCode>
        </ObjectType>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD005</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <FormalAbbreviatedNameText>Intel</FormalAbbreviatedNameText>
  </Unit>
  <ReportingDataAbsoluteTiming>
    <!-- ReportingData for associating 1 CA Brigade and the Intelligence unit with their types -->
    <OID>RPTD005</OID>
    <CategoryCode>REP</CategoryCode>
    <ReportingDatetime>20020102000000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI5</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20020102000000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
</JC3IEDM>
```

A.3. Incremental Information Exchange

A.3.1. Initial Type Information Exchange on 02 January 2002

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
  <!--
    9.6 Example of Using a Facility as Part of an Obstacle

    9.6.1 ...

    9.6.2 The sequence of events is as follows:
      a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
         of three components: two minefields and a demolished bridge.
      b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
      c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
      d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
         Obstacle Alpha becomes operational in its entirety.
  -->
  <!-- Initial information exchange on 02 January 2002 -->
  <MilitaryObstacleType>
    <!-- MilitaryObstacleType of the minefields -->
    <OID>OT1</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>LandMinefield</NameText>
    <CategoryCode>MINEFD</CategoryCode>
  </MilitaryObstacleType>
  <BridgeType>
    <!-- BridgeType for White Horse Bridge -->
    <OID>OT3</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>Iron Horse</NameText>
    <DesignTypeCode>CNTLVR</DesignTypeCode>
  </BridgeType>
  <MilitaryObstacleType>
    <!-- MilitaryObstacleType of Obstacle Alpha -->
    <OID>OT4</OID>
    <DummyIndicatorCode>NO</DummyIndicatorCode>
    <NameText>Compound obstacle</NameText>
    <CategoryCode>NOS</CategoryCode>
  </MilitaryObstacleType>
  <Unit>
    <!-- Unit that is reporting its activities -->
    <OID>OI6</OID>
    <NameText>1 CA Bde</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectType xsi:type="UnitType">
          <OID>OT6</OID>
          <DummyIndicatorCode>NO</DummyIndicatorCode>
          <NameText>CA Brigade</NameText>
          <CommandFunctionIndicatorCode>YES</CommandFunctionIndicatorCode>
          <ServiceCode>ARMY</ServiceCode>
          <CategoryCode>COMBAT</CategoryCode>
          <ArmCategoryCode>INF</ArmCategoryCode>
          <SizeCode>BDE</SizeCode>
        </ObjectType>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD005</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <FormalAbbreviatedNameText>1 CA Bde</FormalAbbreviatedNameText>
  </Unit>
  <Unit>
    <!-- Unit that first recorded the White Horse Bridge -->
```

```
    <OID>OI5</OID>
    <NameText>Intelligence</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectType xsi:type="UnitType">
          <OID>OT5</OID>
          <DummyIndicatorCode>NO</DummyIndicatorCode>
          <NameText>Intelligence</NameText>
          <CommandFunctionIndicatorCode>NO</CommandFunctionIndicatorCode>
          <ServiceCode>JOINT</ServiceCode>
          <!-- check category code -->
          <CategoryCode>COMSPT</CategoryCode>
          <ArmCategoryCode>MILINT</ArmCategoryCode>
          <SizeCode>BDE</SizeCode>
        </ObjectType>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD005</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <FormalAbbreviatedNameText>Intel</FormalAbbreviatedNameText>
  </Unit>
  <ReportingDataAbsoluteTiming>
    <!-- ReportingData for associating 1 CA Brigade and the Intelligence unit with their types -->
    <OID>RPTD005</OID>
    <CategoryCode>REP</CategoryCode>
    <ReportingDatetime>20020102000000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI5</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20020102000000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
</JC3IEDM>
```

A.3.2. Contingency Plan Creation on 22 October 2003

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
  <!--
    9.6 Example of Using a Facility as Part of an Obstacle

    9.6.1 ...

    9.6.2 The sequence of events is as follows:
      a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
           of three components: two minefields and a demolished bridge.
      b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
      c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
      d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
           Obstacle Alpha becomes operational in its entirety.
  -->
  <!-- Information exchange on 22 October 2003 -->
  <MinefieldLand>
    <OID>OI1</OID>
    <NameText>West Minefield</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT1</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
```

```
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <LengthDimension>300</LengthDimension>
    <WidthDimension>105</WidthDimension>
    <IdentificationText>Minefield West</IdentificationText>
    <MineSpacingDimension>10</MineSpacingDimension>
    <DepthPlacementCode>MIXED</DepthPlacementCode>
    <FunctionCode>NUISNC</FunctionCode>
    <PatternCode>REGTHK</PatternCode>
    <PersistenceCode>REMOTE</PersistenceCode>
    <StoppingPowerCode>MEDIUM</StoppingPowerCode>
  </MinefieldLand>
  <MinefieldLand>
    <OID>OI2</OID>
    <NameText>East Minefield</NameText>
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT1</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <LengthDimension>320</LengthDimension>
    <WidthDimension>90</WidthDimension>
    <IdentificationText>Minefield East</IdentificationText>
    <MineSpacingDimension>10</MineSpacingDimension>
    <DepthPlacementCode>MIXED</DepthPlacementCode>
    <FunctionCode>NUISNC</FunctionCode>
    <PatternCode>REGTHK</PatternCode>
    <PersistenceCode>REMOTE</PersistenceCode>
    <StoppingPowerCode>MEDIUM</StoppingPowerCode>
  </MinefieldLand>
  <Bridge>
    <OID>OI3</OID>
    <NameText>White Horse Bridge</NameText>
    <!-- the following tag provides additional information on typing -->
    <ObjectItemTypeInObjectItemList>
      <ObjectItemTypeInObjectItem>
        <ObjectTypeRef>
          <OID>OT3</OID>
        </ObjectTypeRef>
        <ObjectItemType>
          <ReportingDataRef>
            <OID>RPTD001</OID>
          </ReportingDataRef>
        </ObjectItemType>
      </ObjectItemTypeInObjectItem>
    </ObjectItemTypeInObjectItemList>
    <LengthDimension>200</LengthDimension>
    <WidthDimension>10</WidthDimension>
    <LongestSpanLengthDimension>40</LongestSpanLengthDimension>
    <SpanCount>5</SpanCount>
    <UsageCode>RLWYVH</UsageCode>
  </Bridge>
  <MilitaryObstacle>
    <OID>OI4</OID>
    <NameText>Obstacle Alpha</NameText>
    <ObjectItemAssociationInObjectObjectItemList>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI1</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociation>
```

```
        <OID>OIA1</OID>
        <CategoryCode>ISPART</CategoryCode>
        <StatusList>
          <Status>
            <CategoryCode>START</CategoryCode>
            <ReportingDataRef>
              <OID>RPTD711</OID>
            </ReportingDataRef>
          </Status>
        </StatusList>
      </ObjectItemAssociation>
    </ObjectItemAssociationInObjectObjectItem>
    <ObjectItemAssociationInObjectObjectItem>
      <SubjectObjectItemRef>
        <OID>OI2</OID>
      </SubjectObjectItemRef>
      <ObjectItemAssociation>
        <OID>OIA2</OID>
        <CategoryCode>ISPART</CategoryCode>
        <StatusList>
          <Status>
            <CategoryCode>START</CategoryCode>
            <ReportingDataRef>
              <OID>RPTD711</OID>
            </ReportingDataRef>
          </Status>
        </StatusList>
      </ObjectItemAssociation>
    </ObjectItemAssociationInObjectObjectItem>
    <ObjectItemAssociationInObjectObjectItem>
      <SubjectObjectItemRef>
        <OID>OI3</OID>
      </SubjectObjectItemRef>
      <ObjectItemAssociation>
        <OID>OIA4</OID>
        <CategoryCode>ISPART</CategoryCode>
        <StatusList>
          <Status>
            <CategoryCode>START</CategoryCode>
            <ReportingDataRef>
              <OID>RPTD711</OID>
            </ReportingDataRef>
          </Status>
        </StatusList>
      </ObjectItemAssociation>
    </ObjectItemAssociationInObjectObjectItem>
  </ObjectItemAssociationInObjectObjectItemList>
  <ObjectItemTypeInObjectItemList>
    <ObjectItemTypeInObjectItem>
      <ObjectTypeRef>
        <OID>OT4</OID>
      </ObjectTypeRef>
      <ObjectItemType>
        <ReportingDataRef>
          <OID>RPTD001</OID>
        </ReportingDataRef>
      </ObjectItemType>
    </ObjectItemTypeInObjectItem>
  </ObjectItemTypeInObjectItemList>
  <StatusList>
    <Status xsi:type="FacilityStatus">
      <HostilityCode>FR</HostilityCode>
      <ReportingData xsi:type="ReportingData">
        <OID>RPTD703</OID>
        <CategoryCode>PLAN</CategoryCode>
        <CredibilityCode>RPTFCT</CredibilityCode>
        <ReportingDatetime>20031022103000.000</ReportingDatetime>
        <ReportingOrganisationRef>
          <OID>OI6</OID>
        </ReportingOrganisationRef>
```

```
        <TimingCategoryCode>TIMNA</TimingCategoryCode>
      </ReportingData>
      <MinePresenceCode>YES</MinePresenceCode>
      <OperationalStatusCode>NOP</OperationalStatusCode>
      <OperationalStatusQualifierCode>PRPEXE</OperationalStatusQualifierCode>
      <CategoryCode>NOS</CategoryCode>
    </Status>
  </StatusList>
  <LengthDimension>650</LengthDimension>
  <WidthDimension>325</WidthDimension>
  <CategoryCode>NOS</CategoryCode>
 </MilitaryObstacle>
 <ReportingData>
  <OID>RPTD711</OID>
  <CategoryCode>PLAN</CategoryCode>
  <CredibilityCode>RPTFCT</CredibilityCode>
  <ReportingDatetime>20031022103000.000</ReportingDatetime>
  <ReportingOrganisationRef>
    <OID>OI6</OID>
  </ReportingOrganisationRef>
  <TimingCategoryCode>TIMNA</TimingCategoryCode>
 </ReportingData>
 <!--
      the following content provides reference information required to complete the example
  -->
 <ReportingData>
  <!-- ReportingData for associating Obstacle Alpha and its components with their types -->
  <OID>RPTD001</OID>
  <CategoryCode>REP</CategoryCode>
  <CredibilityCode>RPTFCT</CredibilityCode>
  <ReportingDatetime>20031022103000.000</ReportingDatetime>
  <ReportingOrganisationRef>
    <OID>OI6</OID>
  </ReportingOrganisationRef>
  <TimingCategoryCode>TIMNA</TimingCategoryCode>
 </ReportingData>
</JC3IEDM>
```

A.3.3. Activation of Minefield West on 02 November 2003

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
 <!--
   9.6 Example of Using a Facility as Part of an Obstacle

   9.6.1 ...

   9.6.2 The sequence of events is as follows:
     a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
        of three components: two minefields and a demolished bridge.
     b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
     c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
     d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
        Obstacle Alpha becomes operational in its entirety.
 -->
 <!-- Information exchange on 2 November 2003 -->
 <MinefieldLandRef>
  <OID>OI1</OID>
  <StatusList>
   <Status xsi:type="FacilityStatus">
    <HostilityCode>FR</HostilityCode>
    <ReportingData xsi:type="ReportingDataAbsoluteTiming">
     <OID>RPTD701</OID>
     <CategoryCode>REP</CategoryCode>
     <CredibilityCode>RPTFCT</CredibilityCode>
```

```
        <ReportingDatetime>20031102094900.000</ReportingDatetime>
        <ReportingOrganisationRef>
          <OID>OI6</OID>
        </ReportingOrganisationRef>
        <EffectiveStartDatetime>20031102094500.000</EffectiveStartDatetime>
      </ReportingData>
      <MinePresenceCode>YES</MinePresenceCode>
      <OperationalStatusCode>OPR</OperationalStatusCode>
      <UsageStatusCode>ACTIVE</UsageStatusCode>
      <CategoryCode>NOS</CategoryCode>
    </Status>
  </StatusList>
 </MinefieldLandRef>
</JC3IEDM>
```

A.3.4. Activation of Minefield East on 03 November 2003 15:42

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
 <!--
   9.6 Example of Using a Facility as Part of an Obstacle

   9.6.1 ...

   9.6.2 The sequence of events is as follows:
     a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
        of three components: two minefields and a demolished bridge.
     b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
     c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
     d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
        Obstacle Alpha becomes operational in its entirety.
 -->
 <!-- Information exchange on 3 November 2003 15:42 -->
 <MinefieldLandRef>
   <OID>OI2</OID>
   <StatusList>
     <Status xsi:type="FacilityStatus">
       <HostilityCode>FR</HostilityCode>
       <ReportingData xsi:type="ReportingDataAbsoluteTiming">
         <OID>RPTD702</OID>
         <CategoryCode>REP</CategoryCode>
         <CredibilityCode>RPTFCT</CredibilityCode>
         <ReportingDatetime>20031103154200.000</ReportingDatetime>
         <ReportingOrganisationRef>
           <OID>OI6</OID>
         </ReportingOrganisationRef>
         <EffectiveStartDatetime>20031103153000.000</EffectiveStartDatetime>
       </ReportingData>
       <MinePresenceCode>YES</MinePresenceCode>
       <OperationalStatusCode>OPR</OperationalStatusCode>
       <UsageStatusCode>ACTIVE</UsageStatusCode>
       <CategoryCode>NOS</CategoryCode>
     </Status>
   </StatusList>
 </MinefieldLandRef>
</JC3IEDM>
```

A.3.5. White Horse Bridge Prepared for Demolition on 03 November 2003 17:10

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
  <!--
    9.6 Example of Using a Facility as Part of an Obstacle

    9.6.1 ...

    9.6.2 The sequence of events is as follows:
      a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
          of three components: two minefields and a demolished bridge.
      b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
      c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
      d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
          Obstacle Alpha becomes operational in its entirety.
  -->
  <!-- Information exchange on 3 November 2003 17:10 -->
  <BridgeRef>
    <OID>OI3</OID>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingData xsi:type="ReportingData">
          <OID>RPTD704</OID>
          <CategoryCode>REP</CategoryCode>
          <CredibilityCode>RPTFCT</CredibilityCode>
          <ReportingDatetime>20031103171000.000</ReportingDatetime>
          <ReportingOrganisationRef>
            <OID>OI6</OID>
          </ReportingOrganisationRef>
          <TimingCategoryCode>TIMNA</TimingCategoryCode>
        </ReportingData>
        <DemolitionStatusCode>PRPEXE</DemolitionStatusCode>
        <MinePresenceCode>NO</MinePresenceCode>
        <OperationalStatusCode>OPR</OperationalStatusCode>
        <OperationalStatusQualifierCode>PASABL</OperationalStatusQualifierCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
  </BridgeRef>
</JC3IEDM>
```

A.3.6. Obstacle Alpha Becomes Operational on 07 November 2003

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3 ..\..\schema\JC3IEDMSchema.xsd">
  <!--
    9.6 Example of Using a Facility as Part of an Obstacle

    9.6.1 ...

    9.6.2 The sequence of events is as follows:
      a. On 22 October 2003, 1 CA Brigade creates a contingency plan to set up an Obstacle Alpha that consists
          of three components: two minefields and a demolished bridge.
      b. Minefield West is laid and activated on 2 November, followed by Minefield East on 3 November.
      c. The White Horse Bridge is reported to be prepared for demolition on 3 November.
      d. On 7 November, the brigade elements north of the river cross to the south. The bridge is demolished and
          Obstacle Alpha becomes operational in its entirety.
  -->
  <!-- Information exchange on 7 November 2003 -->
  <BridgeRef>
```

```
    <OID>OI3</OID>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
        <ReportingDataRef>
          <OID>RPTD705</OID>
        </ReportingDataRef>
        <DemolitionStatusCode>EXECTD</DemolitionStatusCode>
        <MinePresenceCode>NO</MinePresenceCode>
        <OperationalStatusCode>NOP</OperationalStatusCode>
        <OperationalStatusQualifierCode>DSTRYD</OperationalStatusQualifierCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
  </BridgeRef>
  <MilitaryObstacleRef>
    <OID>OI4</OID>
    <ObjectItemAssociationInObjectObjectItemList>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI1</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociationRef>
          <OID>OIA1</OID>
          <StatusList>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD712</OID>
              </ReportingDataRef>
            </Status>
          </StatusList>
        </ObjectItemAssociationRef>
      </ObjectItemAssociationInObjectObjectItem>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI2</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociationRef>
          <OID>OIA2</OID>
          <StatusList>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD712</OID>
              </ReportingDataRef>
            </Status>
          </StatusList>
        </ObjectItemAssociationRef>
      </ObjectItemAssociationInObjectObjectItem>
      <ObjectItemAssociationInObjectObjectItem>
        <SubjectObjectItemRef>
          <OID>OI3</OID>
        </SubjectObjectItemRef>
        <ObjectItemAssociationRef>
          <OID>OIA4</OID>
          <StatusList>
            <Status>
              <CategoryCode>START</CategoryCode>
              <ReportingDataRef>
                <OID>RPTD712</OID>
              </ReportingDataRef>
            </Status>
          </StatusList>
        </ObjectItemAssociationRef>
      </ObjectItemAssociationInObjectObjectItem>
    </ObjectItemAssociationInObjectObjectItemList>
    <StatusList>
      <Status xsi:type="FacilityStatus">
        <HostilityCode>FR</HostilityCode>
```

```
        <ReportingDataRef>
          <OID>RPTD705</OID>
        </ReportingDataRef>
        <MinePresenceCode>YES</MinePresenceCode>
        <OperationalStatusCode>OPR</OperationalStatusCode>
        <UsageStatusCode>ACTIVE</UsageStatusCode>
        <CategoryCode>NOS</CategoryCode>
      </Status>
    </StatusList>
  </MilitaryObstacleRef>
  <ReportingDataAbsoluteTiming>
    <OID>RPTD705</OID>
    <CategoryCode>REP</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031107081000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20031107080000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
  <ReportingDataAbsoluteTiming>
    <OID>RPTD712</OID>
    <CategoryCode>REP</CategoryCode>
    <CredibilityCode>RPTFCT</CredibilityCode>
    <ReportingDatetime>20031107081000.000</ReportingDatetime>
    <ReportingOrganisationRef>
      <OID>OI6</OID>
    </ReportingOrganisationRef>
    <EffectiveStartDatetime>20031107080000.000</EffectiveStartDatetime>
  </ReportingDataAbsoluteTiming>
</JC3IEDM>
```

An Object-Oriented XML Schema for the MIP Joint Command, Control, and Consultation Information Exchange Data Model

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2006 CCRTS

June 20 – 22, 2006

Overview

- Motivation
- MIP JC3IEDM
- Use Cases, Requirements & Design Principles
- Transformation Rules
- XML Example
- Tool Support
- Summary

Motivation

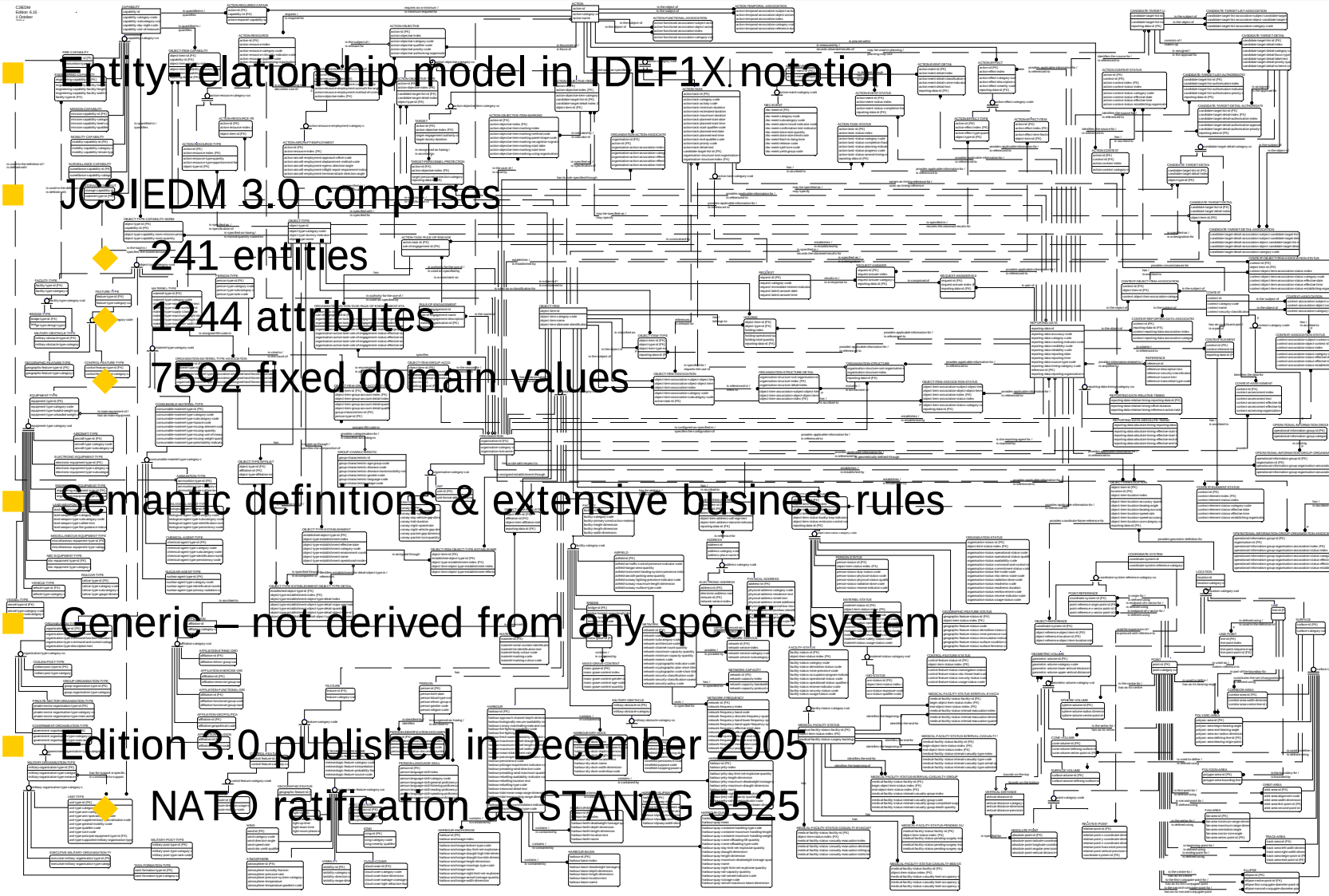
- Multinational interest in the use of **XML for C2 info exchange**
  - National and multinational projects
  - NATO XML Registry

- **Semantic interoperability** is critical to information sharing
  - XML does not automatically ensure common understanding

- **Multilateral Interoperability Programme** (MIP)
  - Voluntary multinational C2 Community of Interest (COI)
  - Supported by 25 nations, NATO, and ACT

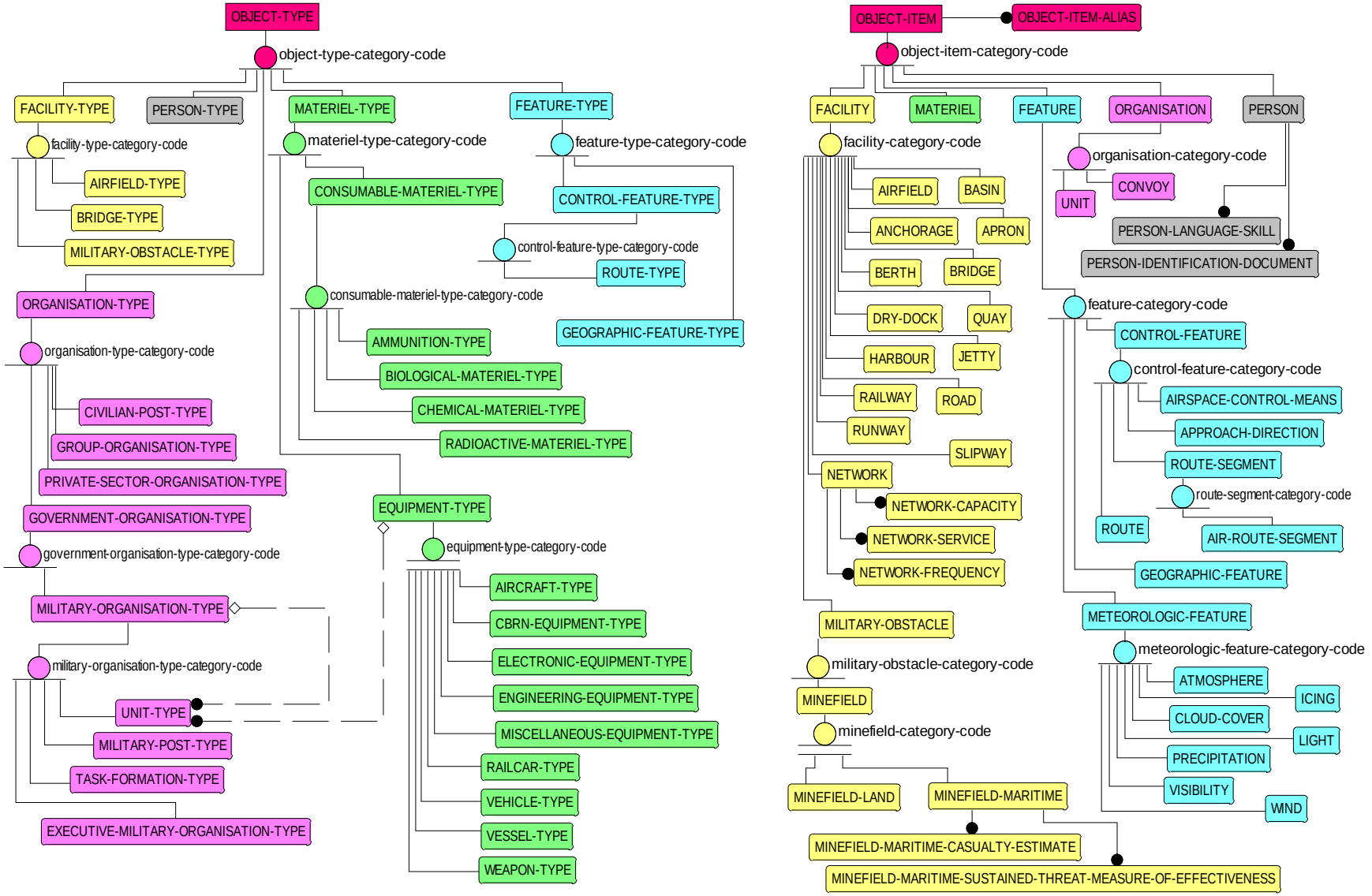
  - Defines the Joint Command, Control, and Consultation Information Exchange Data Model (JC3IEDM)

MIP Information Exchange Data Model



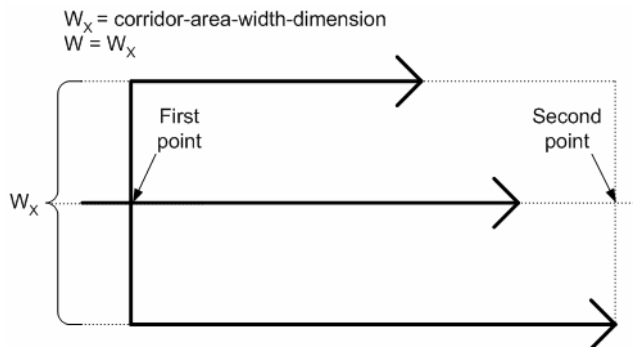
- Entity-relationship model in IDEF1X notation
- JC3IEDM 3.0 comprises
  - 241 entities
  - 1244 attributes
  - 7592 fixed domain values
- Semantic definitions & extensive business rules
- Generic – not derived from any specific system
- Edition 3.0 published in December 2005
  - NATO ratification as STANAG 5525

MIP JC3IEDM – Modeling Capabilities (1)



MIP JC3IEDM – Modeling Capabilities (2)

- **Militarily relevant objects**
  - Current status and location
  - Nominal/actual capabilities & equipment
  - Geopolitical, ethnic, religious, and functional affiliations
  - ORBAT & task organization
  - Addresses
- **Locations/Geometry**
  - Points, lines, surfaces, volumes
  - Relative vs. absolute locations



MIP JC3IEDM – Modeling Capabilities (3)

- **Actions**
  - Temporal and functional relationships
  - Rules of engagement
  - Targets
- ...
- **Meta information**
  - Reporting organization
  - Reporting date & time
  - Accuracy, credibility, reliability
  - Duration of validity
  - etc.

MIP JC3IEDM – XML Use Cases

- **Data Exchange**
  - Web Services (e.g., exchange of business objects)
  - Exchange with non-MIP databases
  - MIP XML Exchange Mechanism

- **Transformation Services**
  - Supporting tactical communications interfaces, ADatP-3 or USMTF (effectively always lossy)
  - Mediation between different versions of the MIP IEDM
  - Export to various output/presentation formats, e.g., STANAG 5500-conformant messages or HTML

Reference MIP XML Schema Definitions

- **Reference MIP XML schema definitions**
  - MIP IEDM defines the C2 XML namespace semantics
  - Avoid diversity of XML vocabularies
  - Collaborative efforts ease national development, improve interoperability, and reduce national costs

- Two reference XSDs for different purposes
  - **RDBMS XSD** – Used for database replication
  - **WS/OO XSD** – Used for web services/SOAs

WS/OO XSD – Requirements (1)

- **Message exchange**
  - Referentially complete, self-contained messages
  - Ensure referential integrity within a single XML document
  - Describe cyclic data structures
  - Allow tailoring to specific business object XSDs
  - No fragmentation of data to enhance readability

- **Replication** & **Query-based communication**
  - Initial synchronization, incremental updates
  - Incomplete query results may refer to unknown objects
  - Support references to external information
  - Relax referential integrity checks (to be ensured by web service & client)

WS/OO XSD – Requirements (2)

- Consider **Naming and Design Rules** (NDRs)
  - Naming of XML elements & attributes, schema versioning, modularization, namespaces, (restricted) use of XML Schema constructs, etc.
  - Discovery and reuse of common data elements

- **NATO Guidelines for XML Naming and Design** (GXND)
  - Based on ISO/IEC 11179 (Metadata registry) and ISO 15000-5 (ebXML)

WS/OO XSD – Design Principles

- **Object-Oriented**
  - Structure of instance XML documents matches the natural OO concepts (e.g., inheritance, object identifiers, navigability)
  - Abstraction from the technical aspects of the relational model
  - Abstraction from any underlying persistence mechanism

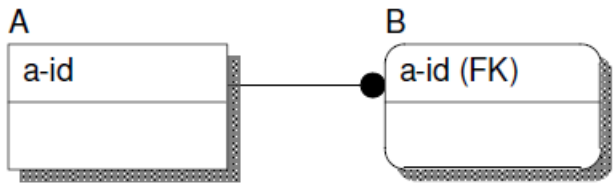
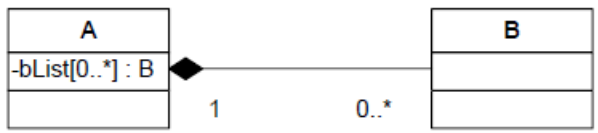
- Based on **Syntactic Transformations** only
  - Suitable for any version of the MIP IEDM
  - Transformations are easily traceable
  - XSD can be generated automatically from the IDEF1X model
  - Minimizes XSD maintenance cost

- Checks **Semantic Constraints**
  - Domain values, optionality, cardinality of relationships
  - Type-safe document consistency

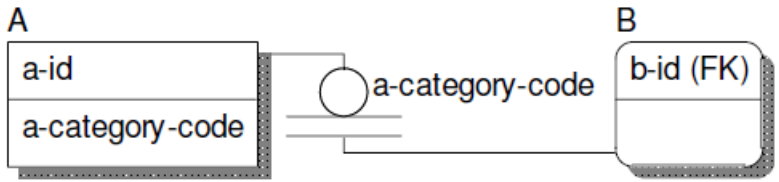
WS/OO XSD – Transformation Rules

- **Names**
  - Simple types, codes, attributes, entities
- **Domains**
  - Simple types and codes
  - Based on predefined XML Schema simple types
- **Entities**
  - Optional and mandatory attributes
  - Object identifiers replace JC3IEDM's synthetic keys
- **Relationships**
  - One-to-many relationships
  - Sub-type relationships
  - Many-to-many relationships (associative entities)

Transformation Rules – Identifying Relationships

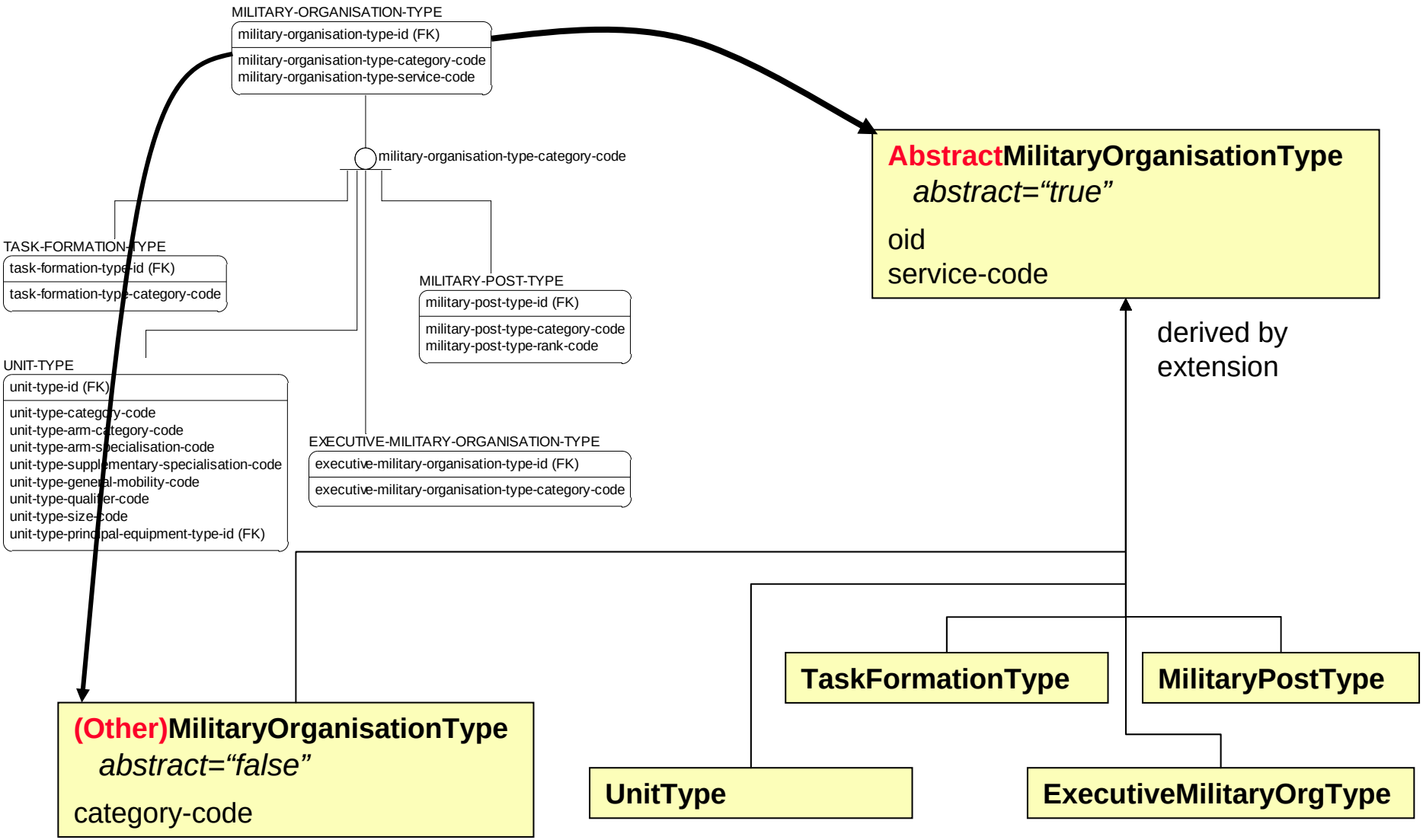
	Design Pattern
IDEF1X	
UML	
XML	<A> <BList> <B>...</B> (inline) <BRef> ... </BRef> (by reference) ... </BList> </A>

Transformation Rules – Subtype Relationships

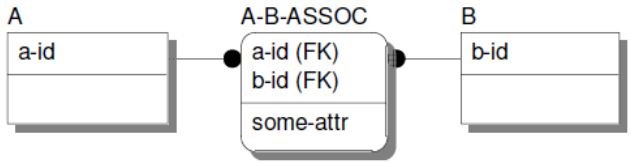
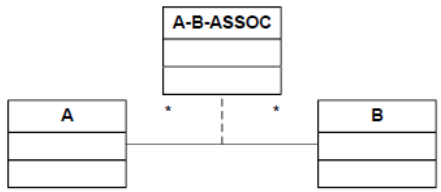
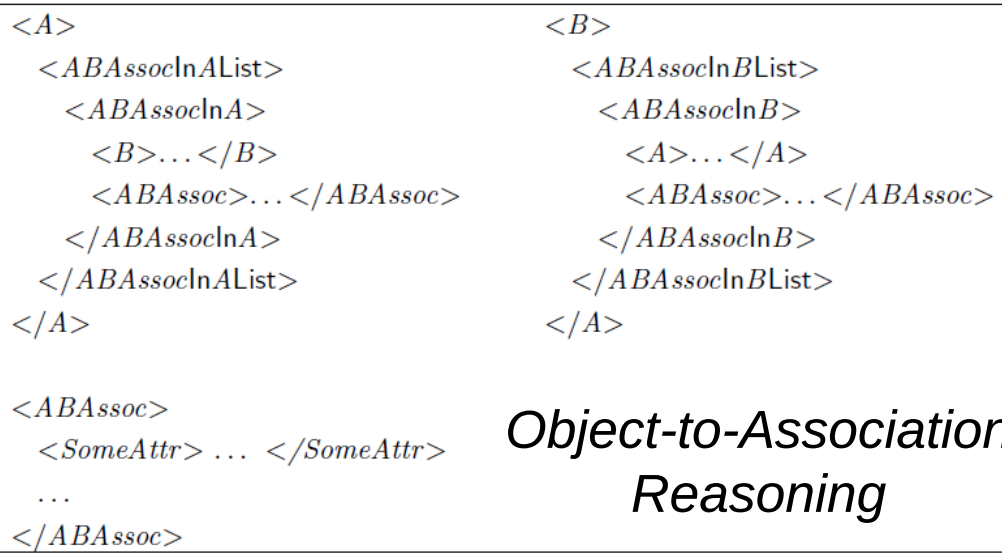
	Design Pattern
IDEF1X	
UML	
XML	$<B>$ $<Attr_1\ of\ A>\ldots</Attr_1\ of\ A>$ $<Attr_2\ of\ A>\ldots</Attr_2\ of\ A>$ $\ldots$ $<Attr_1\ of\ B>\ldots</Attr_1\ of\ B>$ $\ldots$ $</B>$

Drop category codes

Transformation Rules – Incomplete Subtyping



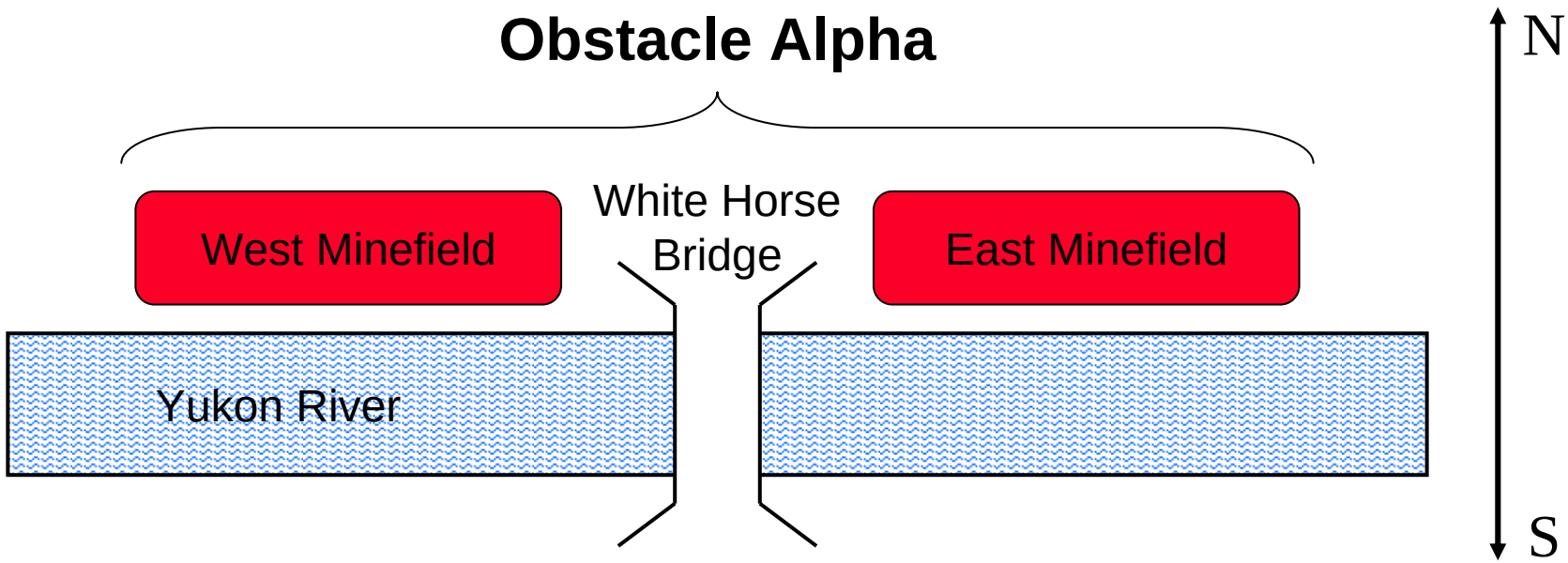
Transformation Rules – Associative Entities

	Design Pattern
IDEF1X	
UML	
XML	

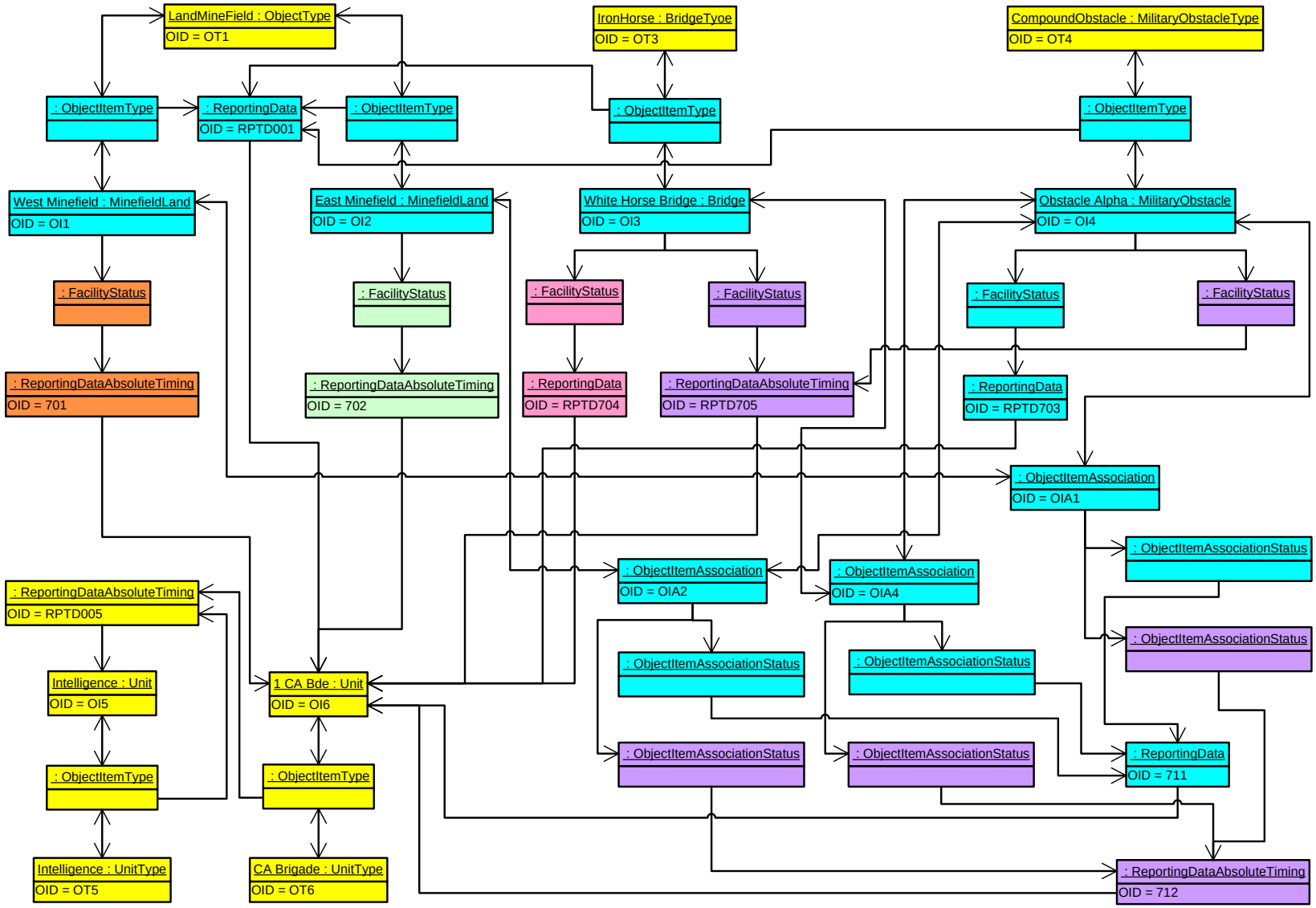
WS/OO Example – Description

- The White Horse Bridge across the Yukon River initially serves as a passage between two minefields located on the north side of the river, one on each side of the bridge. The contingency plan is to use the bridge as part of an obstacle. If the units of the joint task force that are now deployed on the north side of the river need to withdraw, the bridge will be demolished to become part of the main obstacle.

Source: JC3IEDM 3.0 Main Document



WS/OO Example – JC3IEDM Modeling



XML Document – Top-Level Structure

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="...">
    <MinefieldLand>
        <OID>OI1</OID>
        <NameText>West Minefield</NameText>
        ...
    </MinefieldLand>
    ...
    <Bridge>
        <OID>OI3</OID>
        <NameText>White Horse Bridge</NameText>
        ...
    </Bridge>
    <MilitaryObstacle>
        <OID>OI4</OID>
        <NameText>Obstacle Alpha</NameText>
        ...
    </MilitaryObstacle>
    ...
    <ReportingDataAbsoluteTiming>
        <OID>RPTD705</OID>
        ...
    </ReportingDataAbsoluteTiming>
    ...
</JC3IEDM>
```

Object Identifiers (OIDs) for referable entities

- Independent entities
- Elements that can be further specified (e.g., associations with statuses)

XML Document – Entities

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="...">
    <MinefieldLand>
        <OID>OI1</OID>
        <NameText>West Minefield</NameText>
        ...
        <LengthDimension>300</LengthDimension>
        <WidthDimension>105</WidthDimension>
        <MineSpacingDimension>10</MineSpacingDimension>
        <DepthPlacementCode>MIXED</DepthPlacementCode>
        <FunctionCode>NUISNC</FunctionCode>
        <PatternCode>REGTHK</PatternCode>
        <PersistenceCode>REMOTE</PersistenceCode>
        <StoppingPowerCode>MEDIUM</StoppingPowerCode>
    </MinefieldLand>
    <Bridge>
        <OID>OI3</OID>
        <NameText>White Horse Bridge</NameText>
        <LengthDimension>200</LengthDimension>
        <WidthDimension>10</WidthDimension>
        <LongestSpanLengthDimension>40
            </LongestSpanLengthDimension>
        <SpanQuantity>5</SpanQuantity>
        <UsageCode>RLWYVH</UsageCode>
    </Bridge>
</JC3IEDM>
```

- Inheritance of attributes
- Domain value checks (including NULL)

XML Document – Bridge With Status Information

```
<Bridge>
    <OID>OI3</OID>
    <NameText>White Horse Bridge</NameText>
    ...
    <StatusList>
        <Status xsi:type="FacilityStatus">
            <HostilityCode>FR</HostilityCode>
            <ReportingData xsi:type="ReportingData">
                <OID>RPTD704</OID>
                ...
                <ReportingDatetime>20031103171000.000</ReportingDatetime>
                ...
            </ReportingData>
            <DemolitionStatusCode>PRPEXE</DemolitionStatusCode>
            ...
        </Status>
        <Status xsi:type="FacilityStatus">
            <HostilityCode>FR</HostilityCode>
            <ReportingDataRef>
                <OID>RPTD705</OID>
            </ReportingDataRef>
            <DemolitionStatusCode>EXECTD
                </DemolitionStatusCode>
            ...
        </Status>
    </StatusList>
    ...
</Bridge>
```

- Relationships by nesting
- Cardinality/Optionality checks
- Type-safe referential integrity checks

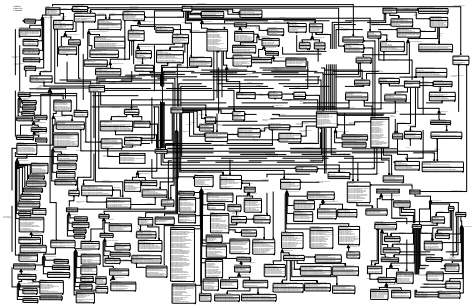
XML Document – Status Update

```
<?xml version="1.0" encoding="UTF-8"?>
<JC3IEDM xmlns="..." xmlns:xsi="..." xsi:schemaLocation="...">
    <!-- This document is used for the information exchange on 3 November 2003 17:10 -->
    <BridgeRef>
        <OID>OI3</OID>
        <StatusList>
            <Status xsi:type="FacilityStatus">
                <HostilityCode>FR</HostilityCode>
                <ReportingData xsi:type="ReportingData">
                    <OID>RPTD704</OID>
                    <CategoryCode>REP</CategoryCode>
                    <CredibilityCode>RPTFCT</CredibilityCode>
                    <ReportingDatetime>20031103171000.000</ReportingDatetime>
                    <ReportingOrganisationRef>
                        <OID>OI6</OID>
                    </ReportingOrganisationRef>
                    <EntityCategoryCode>OIASST</EntityCategoryCode>
                    <TimingCategoryCode>TIMNA</TimingCategoryCode>
                </ReportingData>
                <DemolitionStatusCode>PRPEXE</DemolitionStatusCode>
                <MinePresenceCode>NO</MinePresenceCode>
                <OperationalStatusCode>OPR</OperationalStatusCode>
                <OperationalStatusQualifierCode>PASABL</OperationalStatusQualifierCode>
                <CategoryCode>NOS</CategoryCode>
            </Status>
        </StatusList>
    </BridgeRef>
</JC3IEDM>
```

Reference to existing bridge

Tool Support – Automatic Generation

Data model in
ERwin XML format



Syntactic
Transformations

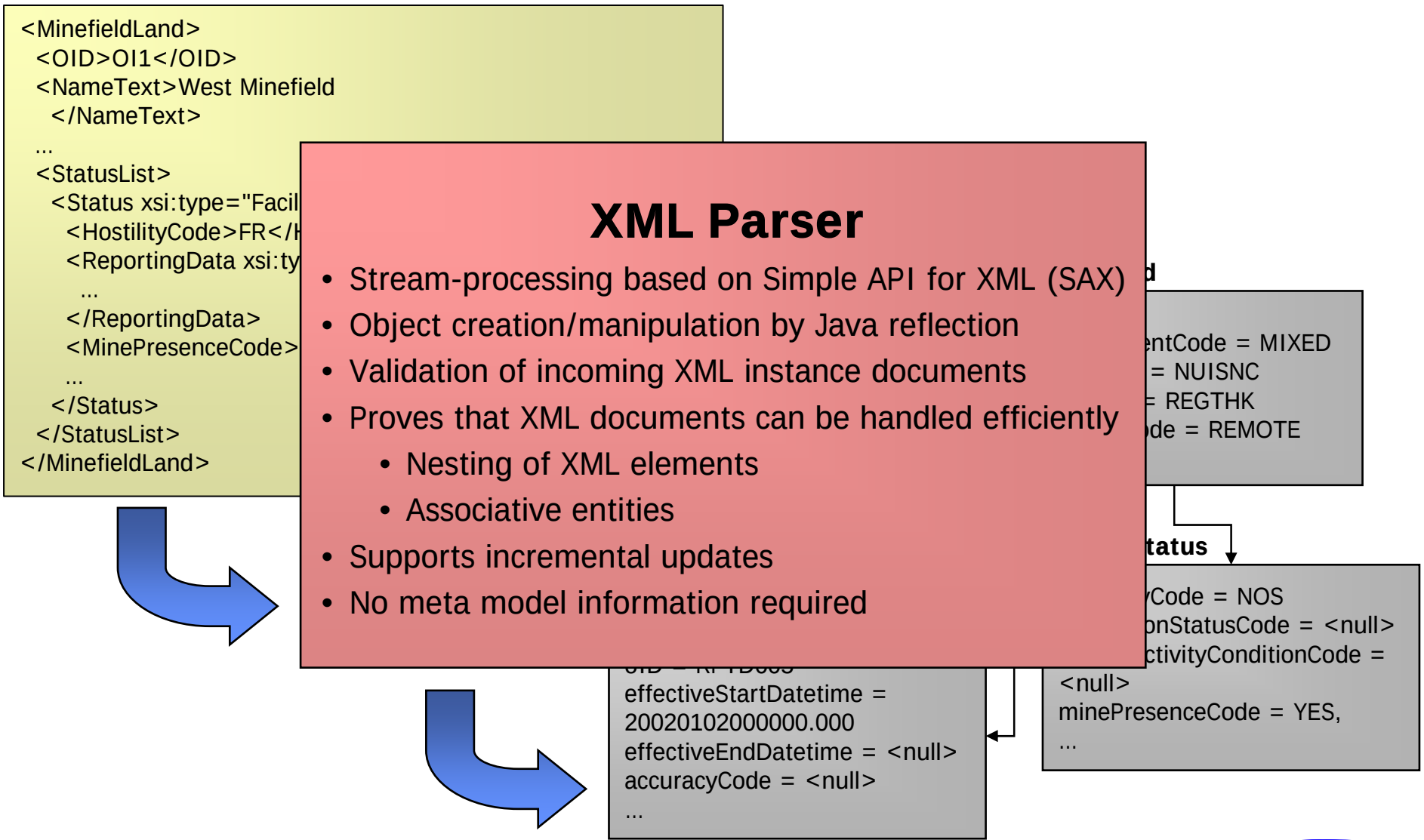
XML
Schema
Definition

```
<?xml version="1.0" encoding="UTF-8"?>
<schema xmlns=http://www.w3.org/2001/XMLSchema
  xmlns:jc3iedm="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
  targetNamespace="urn:int:nato:standard:mip:jc3iedm3.0:oo:1.3"
  elementFormDefault="qualified" attributeFormDefault="unqualified">
 <include schemaLocation="JC3IEDMEntities.xsd" />
 <element name="JC3IEDM">
  <complexType>
   <choice minOccurs="1" maxOccurs="unbounded">
    <element name="ActionContext" type="jc3iedm:ActionContext" />
    <element name="ActionContextRef" type="jc3iedm:ActionContextRef" />
    ...
   </choice>
  </complexType>
 </element>
</schema>
```

Java
Classes

```
package model.entity;
import generic.*;
public abstract class AbstractAbsolutePoint extends AbstractPoint {
 // private fields
 private Ref<VerticalDistance> verticalDistance; // optional
 // default constructor
 public AbstractAbsolutePoint() {
  // no assignment
 }
 // getter & setter methods
 public Ref<VerticalDistance> getVerticalDistance() {
  return verticalDistance;
 }
 public void setVerticalDistance(Ref<VerticalDistance> verticalDistance) {
 this.verticalDistance = verticalDistance;
 }
}
```

Tool Support – XML Unmarshalling



Findings

- **Naming and Design Rules** only partially suitable
  - JC3IEDM follows its own naming conventions
  - Contradictions between different NDRs
- Standard **XML Binding Frameworks**
  - Resolution of graph structures by XML's ID/IDREF mechanism
  - Incremental updates require a more flexible reference mechanism
- **W3C XML Schema**
  - Uniqueness & referential constraints by naming conventions
  - Type model of XML Schema cannot be used
  - Technically complicated solution, difficult to extend

WS/OO XSD – Products

- **XML Design Specification**
  - Standardized as Annex O of the JC3IEDM 3.0
- **WS/OO Tool Set**
  - XML schema definition, XSD/Java generator, XML examples
  - Generator written in Java 5 SE
  - Eclipse 3.1 project
  - Berkeley Software Distribution (BSD) license
- **Available on the MIP web site**
  - http://www.mip-site.org

Summary

- MIP WS/OO XSD as a means to **harmonize C2IS**
  - XML standard data elements derived from widely accepted data model
  - Based on JC3IEDM semantics
- Foundation for **Web Services and SOAs**
  - Abstracts from ER-specific properties of the MIP IEDM
  - Simplified integration into Non-MIP systems
- Supports a broad scope of XML applications
  - Various information exchange mechanisms
  - Builds a bridge between **message-based** and **replication-based communication**
- Future work
  - Update to the next version of the JC3IEDM (End of 2006)
  - Formal representation of **business rules**
  - **RDF** and **OWL** representations